Cerebrovascular Diseases

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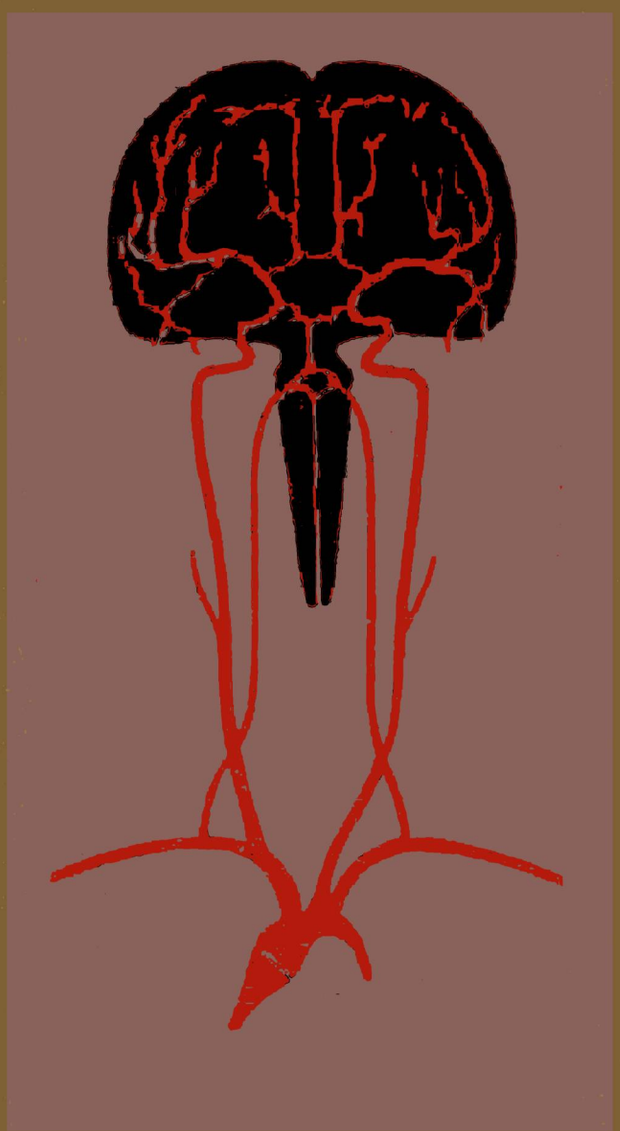

Mir Publishers Moscow

The book presents modern concepts of the vascular pathology of the brain and systematizes all known forms of cerebrovascular diseases. Special attention is drawn to contemporary methods for the prevention and therapy of stroke. The book covers urgent aspects of therapy of cerebrovascular diseases, synthesizing the data of clinical, physiological, experimental, pathomorphological, electron microscopic, various diagnostic, physiological and epidemiological studies. The authors considered not only relevant publications but also the results of many years' research in the clinic of nervous diseases of the Pirogov Second Moscow Medical Institute and in the laboratory of brain ultrastructure of the Institute of the Brain (USSR, AMS).

The book is illustrated with drawings and photographs revealing the results of the latest methods of study. It is intended for neurologists, neurosurgeons, and internists.

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E. I. GUSEV, N. N. BOGOLEPOV, G. S. BURD

Translated from the Russian
by Michael Burov

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First published 1982
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На английском языке

Contents


ИЗДАТЕЛЬСТВО
МИР

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СОСУДИСТЫЕ ЗАБОЛЕВАНИЯ ГОЛОВНОГО МОЗГА

ИЗДАТЕЛЬСТВО «МЕДИЦИНА» МОСКВА

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Introduction

Cerebrovascular diseases are the commonest diseases of the nervous system producing a high disablement and mortality rate. The mortality rate from brain diseases is about 12 per cent of the total for economically developed countries, ranking third as a cause of death from heart diseases and tumours of various localizations. There is a trend for a high mortality rate from cardiovascular diseases among other causes of death, which is largely accounted for by a greater life span and ageing of the population. Other factors contributing to the development of cardiovascular diseases include certain changes in the conditions of life, such as urbanization or sophistication of labour processes, which require greater emotional and psychic strain. Another negative factor is decreased motor activity.

Cerebral stroke is found in almost half of the patients under 60 years of age, i.e. not uncommonly it affects people at the peak of their creative potential. Thus, annual incidence of cerebral stroke for the USA is about 400 thousand cases; a little less than half of these patients die while most of the others become invalids and need constant care. Of all neurological patients in the Soviet Union about 20 per cent are cerebrovascular cases. Therefore the control, prophylaxis and treatment of cerebrovascular diseases are both an important medical and social problem.

For the past decade the studies of the aetiology, pathogenesis and therapy of these diseases have not only become intensive, but also involved a number of fundamentally different novel methodological approaches. They include primarily the use of isotopes, angiography, ultrasound, tomography, electron microscopy, and other research techniques, and elaboration of experimental models for cerebrovascular lesions. As a result new data were obtained on the specific features of cerebral blood flow and microcirculation in health and in disease, on the mechanisms making up for disturbances of cerebral haemodynamics. From this standpoint some traditional

concepts of the pathogenesis and methods of treatment of cerebrovascular disturbances are revised and new approaches advanced.

The most important risk factors such as arterial hypertension, aggravated heredity with regard to cardiovascular diseases, activities connected with emotional and psychic strain, ischaemic heart disease, disorders of lipid metabolism indicate a specific way of the prophylaxis of cerebrovascular diseases.

The study of early signs of cerebrovascular pathology has recently been the focus of attention. The early signs of inadequate blood supply to the brain may arise as a response to the effect of harmful factors long before any marked clinical symptoms of a disease become apparent. Hence, the study of these early shifts contributes to better detection of vascular diseases. The early diagnosis of cerebrovascular disturbances is essential for the prophylaxis of the diseases, elimination of harmful factors, and purposeful treatment.

This handbook covers general concepts of the early and marked signs of insufficient blood supply to the brain, cerebrovascular crisis, stroke, and disorders of cerebral venous circulation.

Chapter 1. Anatomical and Physiological Characteristics of Cerebral Circulation

1.1. Peculiarities of Cerebral Circulation

A characteristic feature of cerebral blood supply is a certain optimal mode of function providing continuous and timely replenishment of its energy and other expenditures. This is carried out by a sequence of activation of several factors putting into action various mechanisms of autoregulation of cerebral circulation. These mechanisms bring about a relative (i.e. within certain limits) independence of cerebral blood flow from changes in general haemodynamics. The volume of cerebral blood flow is regulated mainly by the metabolic activity of the brain matter: enhanced functional activity of the brain or some of its systems intensifies metabolic processes and circulation.

Unlike other organs, the brain has practically no oxygen reserves to produce energy by means of aerobic oxidation of glucose into carbon dioxide and water. That accounts for acute sensitiveness of the nervous tissue to hypoxia which results from decrease or termination of blood inflow into the brain. Man loses consciousness in 5-7 seconds following a stop in cerebral circulation. Consciousness is regained without any signs of lesion in the nervous system if the period of ischaemia has been no longer than 100 seconds. Irreversible damage to the nerve cells of the cerebral cortex develops in case ischaemia lasts over 5 minutes. Some more tolerance to an oxygen deficit is shown by the nerve cells of the philogenetically older parts of the brain: the midbrain up to 10 minutes, the medulla oblongata up to 20-25 minutes.

The loss of the effect observed on restoration of cerebral blood flow after the mentioned lapse of time seems to be connected not only with severe destructive ischaemic changes in the nerve cells, but also with the so-called phenomenon of the absence of capillary perfusion, i.e. phenomenon of non-restoration of blood flow. More than 5 minutes of ischaemia brings about failure of perfusion adequate enough to restore the blood flow in the various areas of the brain because of the cut-off in the capillary part of microcirculation,

i.e. due to the block ensuing from marked change in the capillary endothelium and oedema of the glial elements.

Intensification of brain function does not necessarily call for an additional increase of cerebral blood flow, and in some cases may be accomplished due to blood redistribution within the brain arterial system. Blood is transferred from the regions less active with respect to function to the regions of intense activity. At this moment local blood flow enhances in some regions and decreases in others on a background of stable or, less frequently, somewhat increased cerebral blood flow on the whole. This mechanism of redistribution of blood in the cerebrovascular system, operating to the benefit of its active areas, and hence to the detriment of the less active ones, may cause ischaemia of the latter in some kind of intellectual work; it may be manifested by some stereotyped symptoms of transient disturbances of cerebral circulation. A similar situation may arise also with insufficient inflow of blood to the brain on the whole, when supply of the areas from which blood is 'borrowed' is already critical, or when the compensatory inflow into them fails due to some other reasons. Thus the general pattern of cerebral circulation changes due to change of functional activity in various brain areas, comprising a dynamic mozaic of continuously changing volumes of local blood flow in many areas of the brain substance.

Therefore, in physiological conditions not only the relative stability and independence from the changes in general circulation are distinctive features of cerebral circulation, but also dynamic and differentiated nature of meeting the metabolic demands of the most active areas of the brain. Like in other organs, function, metabolism, and blood supply are tightly interrelated there. Adequacy of cerebral circulation to the conditions under which the brain is functioning is provided both by the structural features of the cerebrovascular system and by the physiological mechanisms of its regulation.

1.2. General Structure of the Cerebrovascular System

The brain is supplied with blood by two pairs of the major vessels of the head — the internal carotid and the vertebral arteries originating from branches of the aortic arch (Fig. 1). Most of the blood flows from the brain by the internal jugular veins and further enters into the right atrium through the superior vena cava.

The major arteries of the head pass into the skull and divide into the cerebral arteries. By means of communicating branches, the

largest of them form at the base of the brain the circle of Willis, one of the most important anastomoses between the systems of the carotid and vertebral arteries and the basilar artery.

The cerebral arteries and their branches form two systems supply-

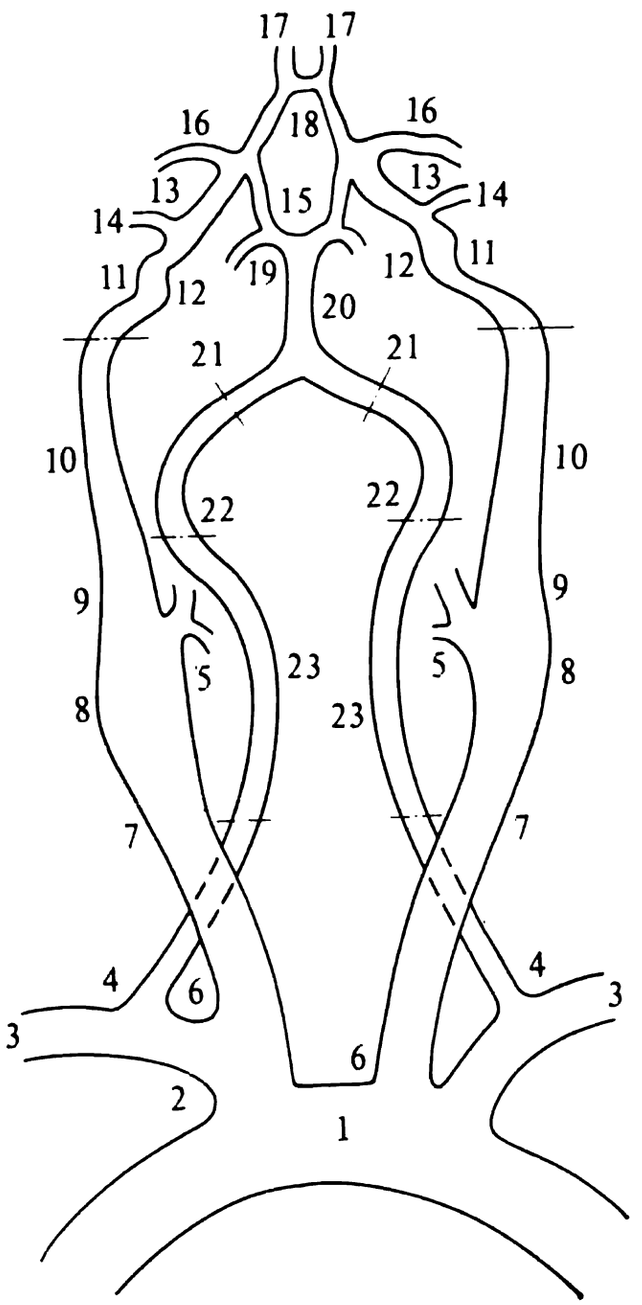


Fig. 1. Diagrammatic representation of the carotid and vertebral arteries, and the vessels of the base of the brain.

1—aortic arch; *2*—brachiocephalic trunk; *3*—subclavian artery; *4*—vertebral artery (initial portion); *5*—external carotid artery (initial portion); *6*—initial portion of the common carotid artery; *7*—middle portion of the common carotid artery; *8*—bifurcation of the common carotid artery; *9*—sinus of the internal carotid artery; *10*—cervical portion of the internal carotid artery; *11*—intraosseous portion of the internal carotid artery; *12*—siphon of the internal carotid artery; *13*—cerebral portion of the internal carotid artery; *14*—ophthalmic artery; *15*—posterior communicating artery; *16*—middle cerebral artery; *17*—anterior cerebral artery; *18*—anterior communicating artery; *19*—posterior cerebral artery; *20*—basilar artery; *21*—intracranial portion of the vertebral artery; *22*—siphon of the vertebral artery; *23*—portion of the vertebral artery situated in the bone canal

ing the brain. One of them has the character of the arterial network which lies in the arachnoid mater and covers the surface of the cerebral hemispheres. Cerebral arteries stem from this vascular system and penetrate the brain matter usually at the right angle and in radial direction. They are of two kinds: short ones, branching into the cortex, and long ones, supplying the underlying white matter. The vascular network of the subcortex formations, the diencephalon, and the brain stem includes two arteries which originate not in the network, but branch directly from the vessels at the base of the brain and go deep into the brain matter.

The intracerebral arteries of the both systems, giving off numerous branches into the brain, compose an uninterrupted vasculocapillary system.

Different brain areas have different qualitative and quantitative angioarchitectonic characteristics depending on the specific features of their structure, function, and the level of metabolism. The thickness of the capillary network in the cortex is 3-4 times finer than in the underlying white matter.

Most of the blood from the postcapillary network of the brain cortex and white matter outflows into the surface venous system of the arachnoid mater; that of the subcortex formations outflows into the deep brain veins. Both systems are connected through numerous interhemispherical and other anastomoses. Further, the venous blood flows into the sinuses, lying deep in the dura mater, and then into the internal jugular veins and partially into the external jugular veins.

The venous system of the brain is characterized by abundance of its branches and anastomoses, many pathways for the outflow, absence of valves, and presence of such major elements as sinuses, which protect the system from compression.

1.3. The Carotid and Vertebrobasilar Systems of the Brain

Two thirds of the whole mass of blood inflowing into the brain, is provided by the internal carotids, and one third by the vertebral arteries. The former form the carotid, and the latter the vertebrobasilar system of the brain blood supply. Extracranial and intracranial portions are distinguished within each of these systems. The carotid system supplies the anterior and middle parts of the brain, while the vertebrobasilar system supplies its posterior parts.

The common carotid artery stems from the brachiocephalic trunk of the innominate artery on the right side, and directly from the aor-

tic arch on the left side. It divides into the internal and external carotid arteries at the level of the third-fourth cervical vertebrae. They collect correspondingly two thirds and one third of the whole volume of blood carried by the common carotids.

A special neurovascular structure with chemoreceptor function is located in the adventitia at the site of the bifurcation of the common artery. The bifurcation and the original parts of both internal and external carotid arteries are especially liable to atherosclerotic change, hence it is so likely to find there a stenosis or thrombosis. The internal carotid artery is considered to be composed of the extracranial portion including two segments: the sinus and the cervical segment, and the intracranial portion, which is composed of 3 parts: intraosseous, siphon, and cerebral segments.

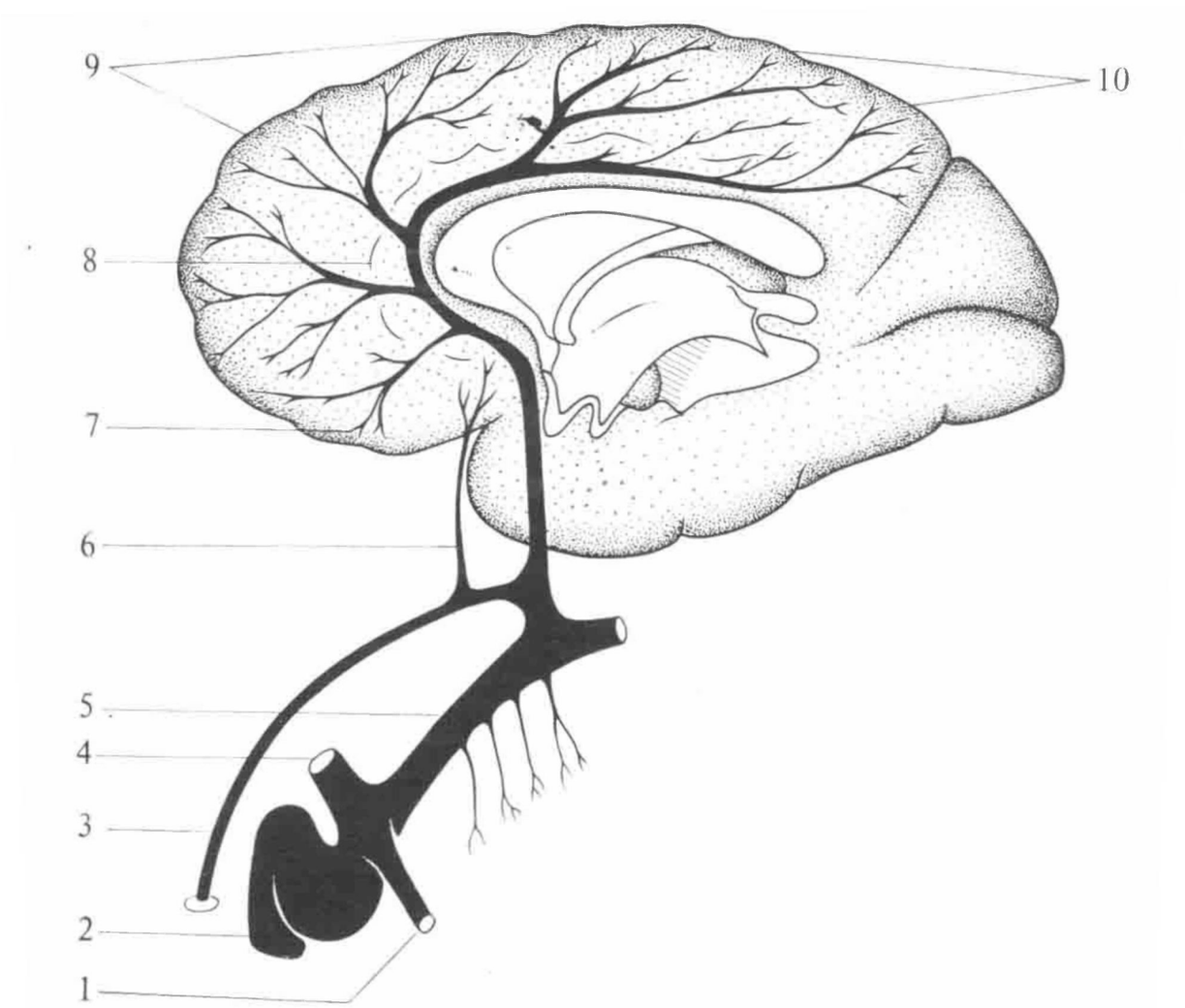


Fig. 2. Diagrammatic representation of the distribution of a. cerebri anterior (according to Kaplan and Ford, 1966)*:

1—proximal stem of a. cerebri posterior (a. communicans posterior); *2*—a. carotis interna; *3*—r. centralis of a. cerebri anterior (a. striatica medialis of Heubner); *4*—a. cerebri media; *5*—a. cerebri anterior; *6*—r. of a striata medialis to septal area; *7*—rr. orbitales; *8*—a. paracallosa with rr. corticales; *9*—rr. frontales; *10*—rr. parietales

* Here and under a number of the following figures only those formations or arteries are pointed out which are mentioned in the text.

The carotid sinus is a considerably expanded initial segment of the internal carotid artery. It is abundantly innervated with baro- and chemoreceptors and plays an important role in circulation control. The cervical segment includes the part of the artery from the sinus to the point of entering the skull. Both these segments do not branch. The extracranial part of the internal carotid is liable

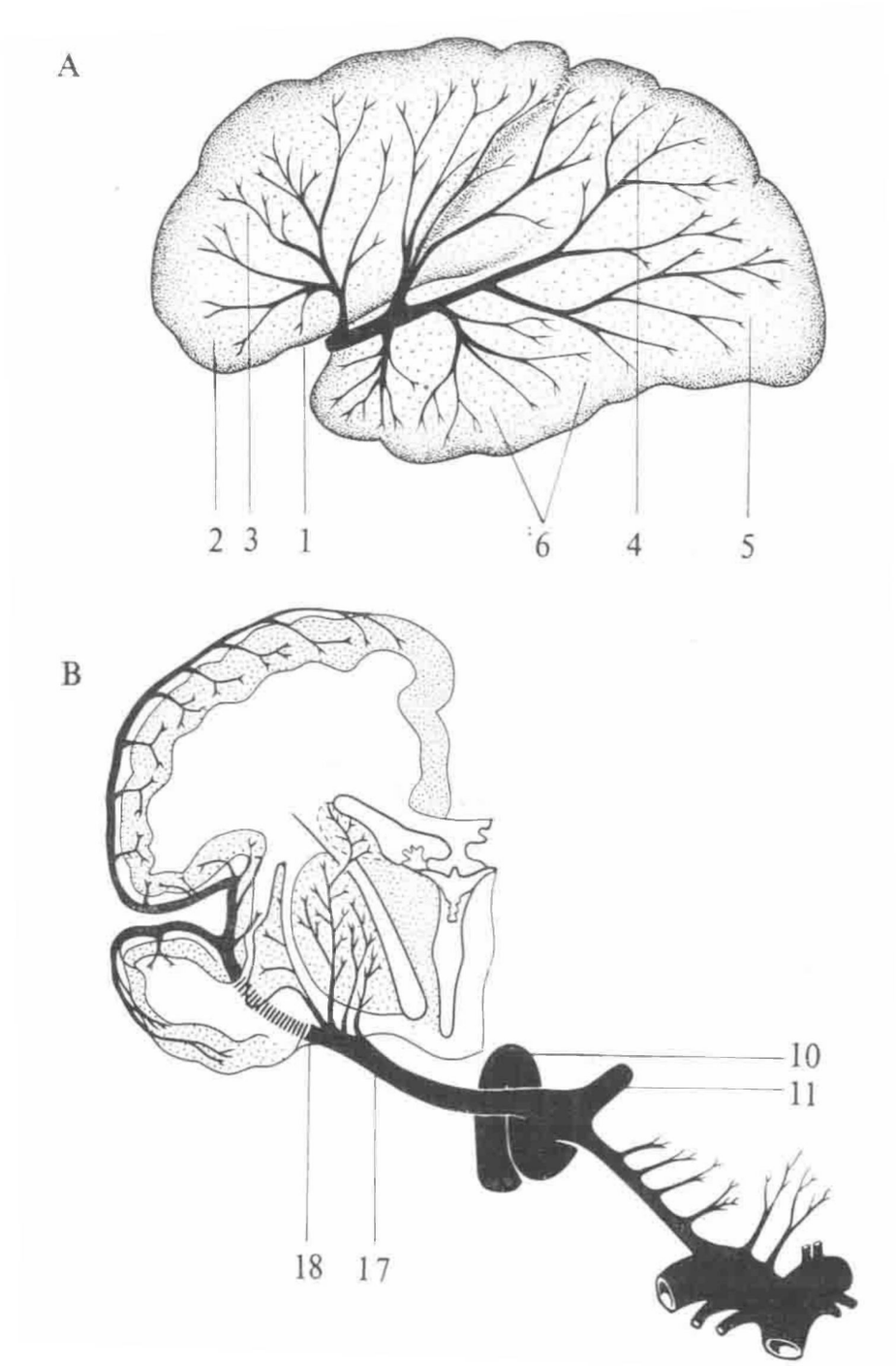


Fig. 3. Sketch depicting the distribution of the various branches of a. cerebri media (according to Kaplan and Ford, 1966):

A, lateral view of the cerebral hemisphere illustrating the distribution of the rr. corticales of a. cerebri media: *1*—a. cerebri media; *2*—rr. orbitales; *3*—rr. frontales; *4*—rr. parietales; *5*—rr. occipitales; *6*—rr. temporales
B, coronal section through the cerebrum to demonstrate the deep nuclear distribution of vessels arising from a. cerebri media: *10*—a. carotis interna; *11*—a. cerebri anterior (stem); *17*—a. cerebri media; *18*—rr. striati (lenticulostriate arteries)

to be affected to a greater extent than elsewhere by various harmful factors, such as a mechanical injury or compression from the outside (e.g. with a haematoma, tumour, cicatricial changes of the surrounding tissues, etc.). They may cause slackening of the blood flow in the artery.

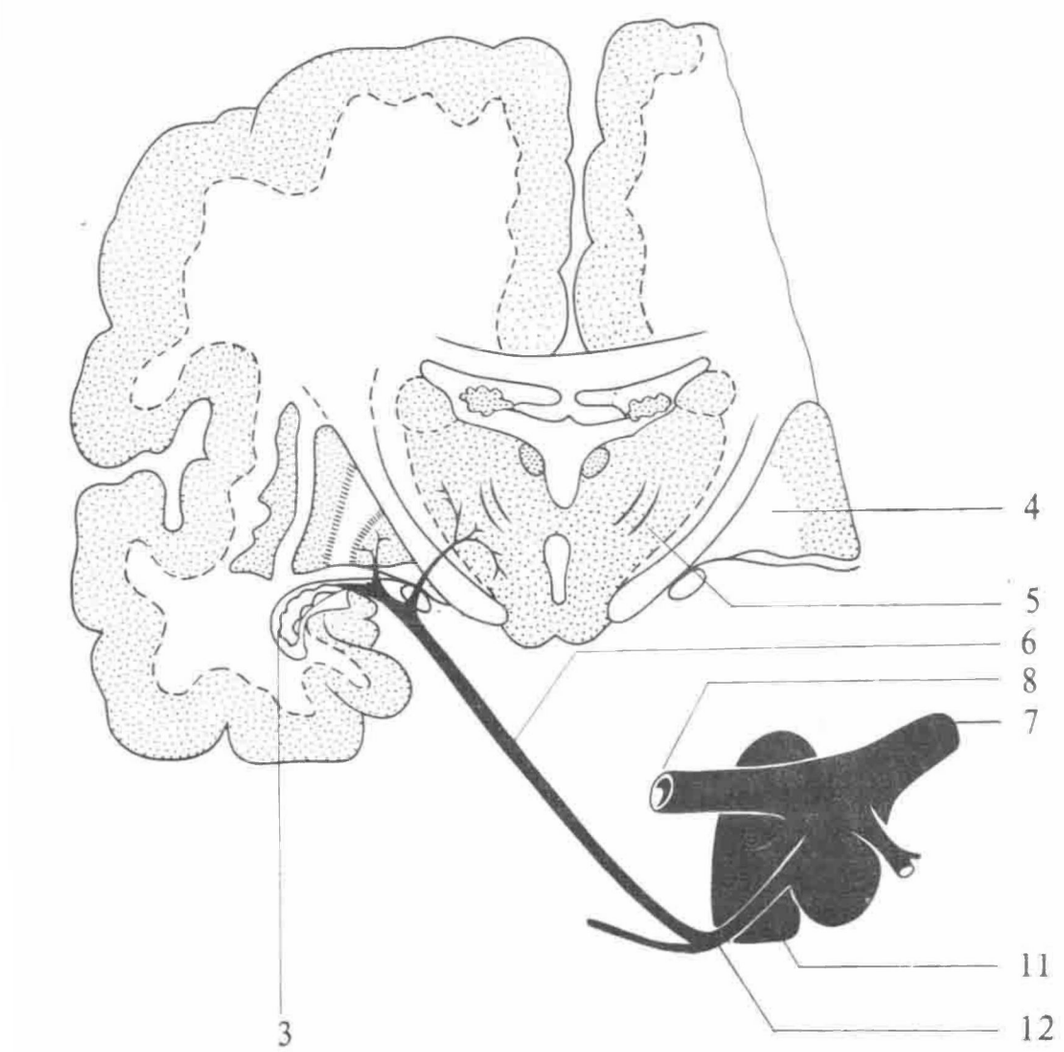


Fig. 4. Diagrammatic representation of the distribution of the various branches of arteria choroidea anterior (according to Kaplan and Ford, 1966)

3—cornu inferius of ventriculus lateralis with choroid plexus; *4*—medial division of globus pallidus; *5*—nucleus ventralis thalami intermedius; *6*—branch of arteria choroidea anterior to choroid plexus, medial division of globus pallidus, nucleus ventralis thalami intermedius and the nuclei interlaminares thalami; *7*—a. cerebri anterior; *8*—a. cerebri media; *11*—a. carotis interna; *12*—a. choroidea anterior

The intraosseous segment of the intracranial portion of the internal carotid artery passes the pyramid of the temporal bone horizontally through a special canal where it is surrounded with a venous plexus. Coming out of the bone canal, inside the skull, the artery penetrates the cavernous venous sinus where it makes an S-like flexure, from the convex of which it gives off its first large branch, the ophthalmic artery. This segment in the cavernous sinus has been

named the siphon. Further, the artery comes through the dura mater into the subarachnoid space. That is where the short cerebral segment of the internal carotid originates. It extends to the point of bifurcation into its two main branches — the anterior (Fig. 2) and middle cerebral arteries (Fig. 3). The anterior artery of the choroid plexus (Fig. 4) and the posterior communicating artery which connects the systems of the carotid and vertebral arteries in the base of the brain also originate there.

The function of the segments of the intracranial portion of the internal carotid is very important. Thus, by means of its own constriction the intraosseous segment of the internal carotid regulates the inflow of blood into the brain. The flexure of the siphon is considered to be the mechanism lowering the pulse variation of arterial pressure. The common carotid is an elastic artery, which is in accord with its main purpose — transportation of blood. The internal carotid is an artery of the musculoelastic type.

The vertebral artery is the first and the largest branch of the subclavian artery originating, like the common carotid artery, from the brachiocephalic trunk on the right side and from the aortic arch on the left side. The vertebral artery has the extracranial part which is considered to have three segments, and the intracranial part, which has no such division.

Clinically, very important is the original segment of the extracranial part, from the point of branching from the upper surface of the subclavian artery to the point of entering the bone canal formed by the foramina of the transverse processes of the seventh to second cervical vertebrae. Atherosclerotic stenosis, frequently revealed in the arterial ostium, often simultaneously narrows the lumina of the vertebral and subclavian arteries. When the vertebral artery arises from the ventral (posterior-inferior) surface of the subclavian, or when its ostium is displaced laterally, there may be a kink or the artery may be compressed by the anterior scalene muscle. Upon entering the above-mentioned bone canal, commonly at the level of the sixth, less often the fifth cervical vertebra, the vertebral artery runs up vertically to the foramen in the transverse process of the second vertebra. This segment of the artery is tightly connected with the bone formations of the cervical spine, the uncovertebral areas, intervertebral foramina, foramina of the transverse vertebral processes. Any change in them may cause displacement or compression of the artery, its nervous plexuses, and accompanying veins. Bony outgrowths (osteophytes) are a common cause of compression of the vertebral arteries. Compression may be also due to subluxation of articular processes or dislocation of the body of a vertebra.

After leaving the bone canal at the level of the second cervical vertebra, the vertebral artery deviates laterally to the outside, comes into the foramen of the transverse process of the atlas, horizon-

tally bends round the lateral surface of its body, then goes up and forward, perforates the atlanto-occipital membrane, and finally enters the cranium through the foramen magnum. Within the boundaries of the precranial segment, the artery makes four bends in various planes. Like the siphon of the internal carotid, the bends reduce the amplitude of the pulse wave and facilitate the regular blood flow.

At the level of the atlas the vertebral artery is surrounded by a special formation—a 'venous sheath', i.e. the atlanto-occipital sinus similar in both its structure and function to the venous cavernous sinus, which envelops the siphon of the internal carotid. Apart from the blood transport function, these segments of both pairs of the major arteries of the head co-ordinately regulate the cerebral blood flow.

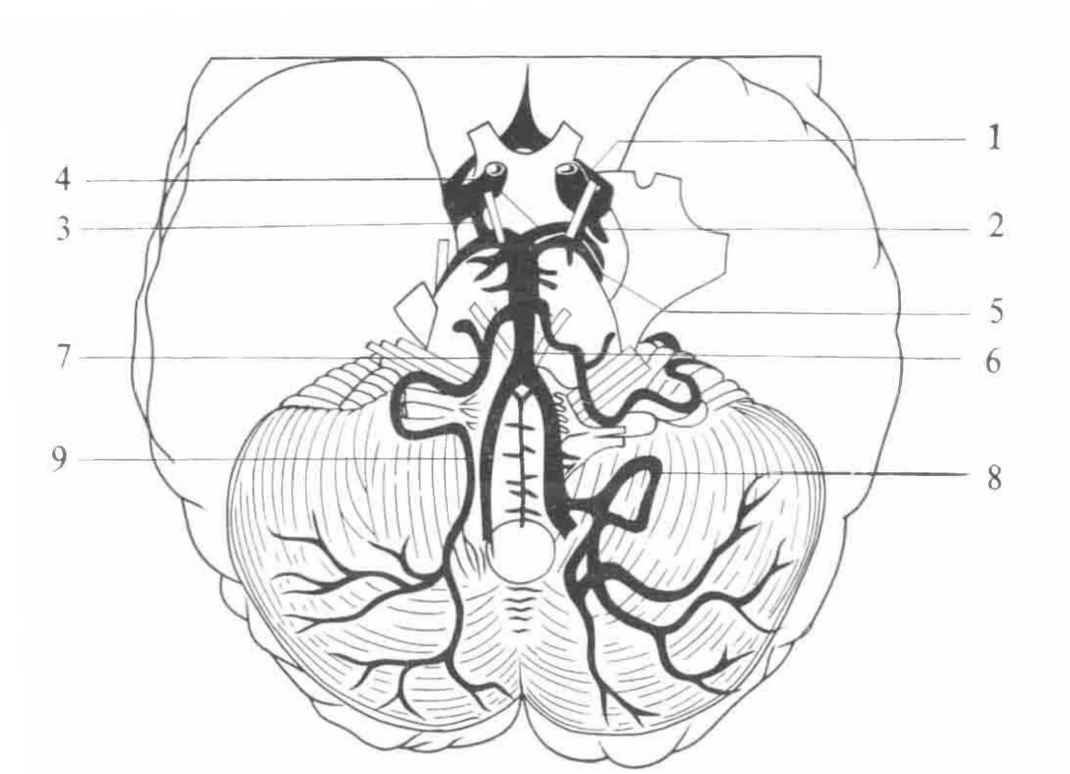


Fig. 5. Diagrammatic representation of the distribution of arteria vertebralis (according to Krayenbühl and Yasargil, 1957).

1—a. carotis interna; *2*—a. choroidea anterior; *3*—a. communicans posterior; *4*—a. cerebralis posterior; *5*—a. cerebellaris superior; *6*—a. basilaris; *7*—a. cerebellaris inferior anterior; *8*—a. cerebellaris inferior posterior; *9*—a. vertebralis

Anomalies of the vertebral arteries (origination from the aortic arch, lateral displacement of the ostium, two-root origination, entering into the processes at the level of the fifth-third vertebrae, hypoplasia, arteriovenous aneurysms) occur much more often than anomalies of the carotids. Their pathogenesis is of relative value, but under certain conditions some of them become prerequisites for developing insufficiency of cerebral circulation.

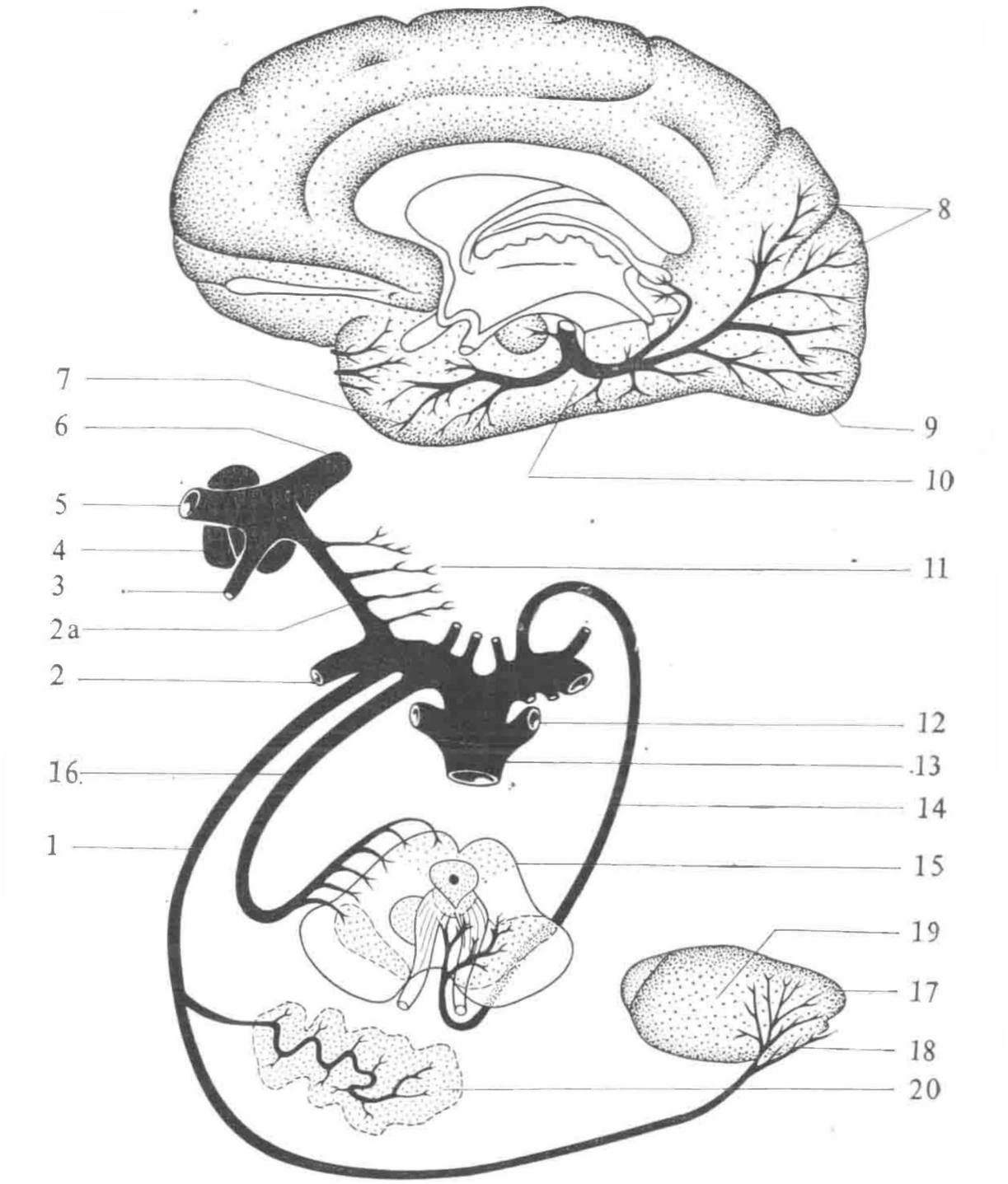


Fig. 6. Diagrammatic representation of the distribution of a. cerebri posterior (according to Kaplan and Ford, 1966):

1—choroidal-diencephalic artery to the choroid plexus and thalamus; *2*—a. cerebri posterior; *2a*—proximal stem of a. cerebri posterior (a. communicans posterior); *3*—a. choroidea anterior; *4*—a. carotis interna; *5*—a. cerebri media; *6*—a. cerebri anterior; *7*—rr. temporales; *8*—rr. parieto-occipitales; *9*—rr. occipitales; *10*—a. cerebri posterior; *11*—perforators from the proximal stem of a. cerebri posterior to the ventral aspect of the diencephalon; *12*—a. cerebelli superior; *13*—a. basilaris; *14*—posteromedial perforators from the a. mesencephalica to the tegmentum mesencephali; *15*—mesencephalon (coronal plane); *16*—r. to tectum mesencephali with branches to the lateral aspect of the mesencephalon (may be more than one branch); *17*—diencephalon; *18*—pulvinar of diencephalon; *19*—geniculate bodies; *20*—choroid plexus

In its extracranial segment the vertebral artery gives off branches to the muscles, as well as to the bones and ligaments of the cervical part of the spinal column and to the meninges of the spinal cord. In its intracranial segment, the artery gives off successively the posterior spinal arteries, branches forming the anterior spinal artery, and the largest branch—the inferior posterior cerebellar artery, after which, at the level of the posterior edge of the pons, it connects with the homonymous artery of the opposite side to form the basilar artery (Fig. 5). There are also multiple fine branches originating from the vertebral arteries and their vertebrospinal branches to form the bulbar arterial circle. The dorsal surface of the basilar artery branches all along its length into small and numerous paramedian arteries. Besides, it has two large branches: the inferior anterior cerebellar artery and the superior cerebellar artery. At the level of the anterior boundary of the pons, the basilar artery divides into the two poste-

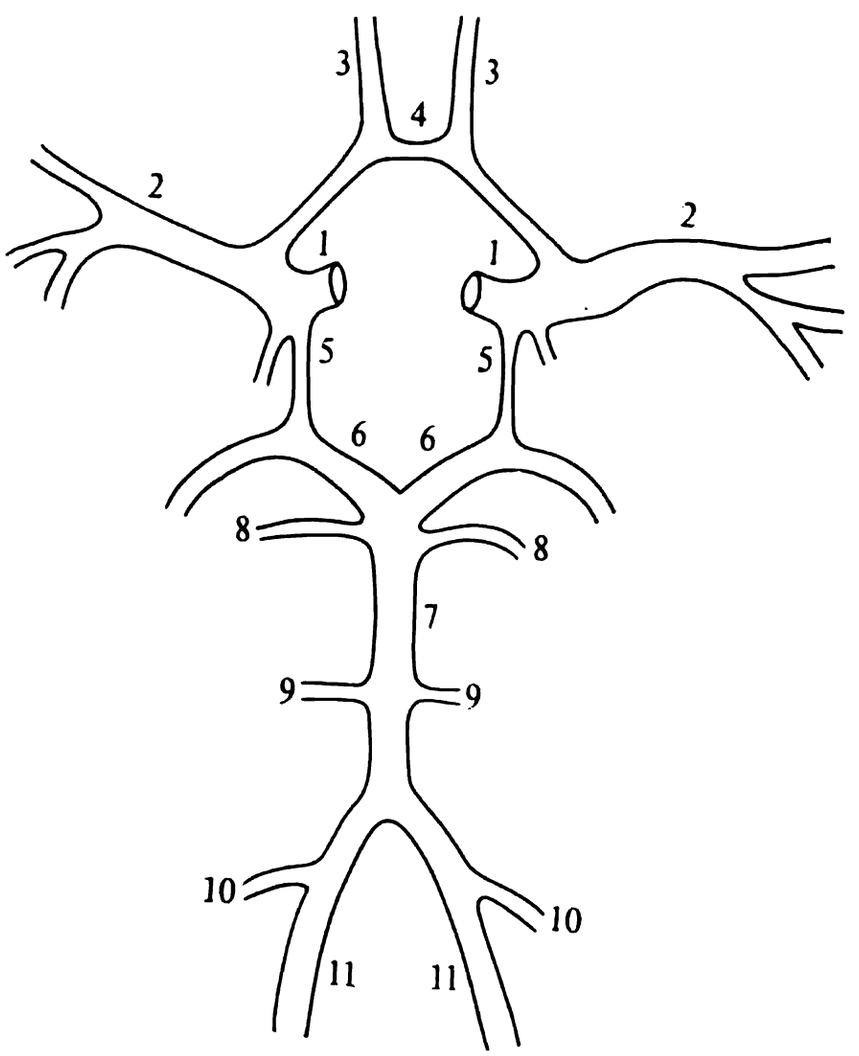


Fig. 7. Diagrammatic representation of the distribution of the vessels in the base of the brain.

1—cerebral portion of the internal carotid artery; *2*—middle cerebral artery; *3*—anterior cerebral artery; *4*—anterior communicating artery; *5*—posterior communicating artery; *6*—posterior cerebral artery; *7*—basilar artery; *8*—superior cerebellar artery; *9*—anterior inferior cerebellar artery; *10*—posterior inferior cerebellar artery; *11*—vertebral artery

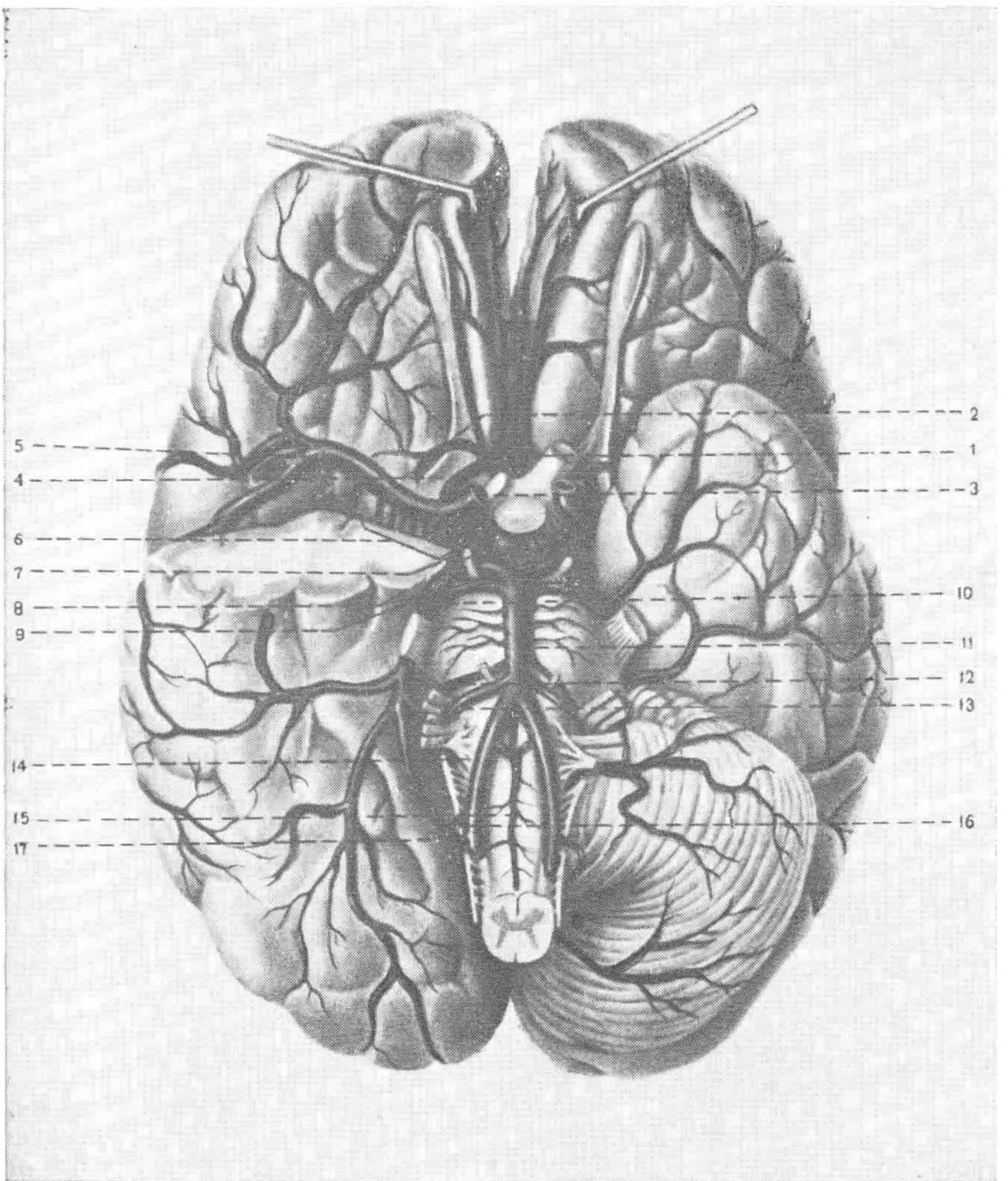


Fig. 8. The arteries of the base of the brain (according to Jackson, 1966).

1—a. communicans anterior; *2*—r. recurrens (a. cerebri anterior); 3—a. carotis interna; *4*—a. cerebri anterior; *5*—a. cerebri media; *6*—rr. striati; *7*—a. choroidea anterior; *8*—a. communicans posterior; *9*—a. cerebri posterior; *10*—a. cerebelli superior; *11*—a. basilaris; *12*—a. labyrinthi; *13*—a. cerebelli inferior anterior; *14*—a. vertebralis; *15*—a. spinalis anterior; *16*—a. cerebelli inferior posterior; *17*—a. spinalis posterior

rior cerebral arteries (Fig. 6), the proximal portions of which, together with the oral segment of the basilar artery, participate in forming the circle of Willis. The vertebral artery in its extracranial part is an artery of the elastic type, while its intracranial part is of the muscular type.

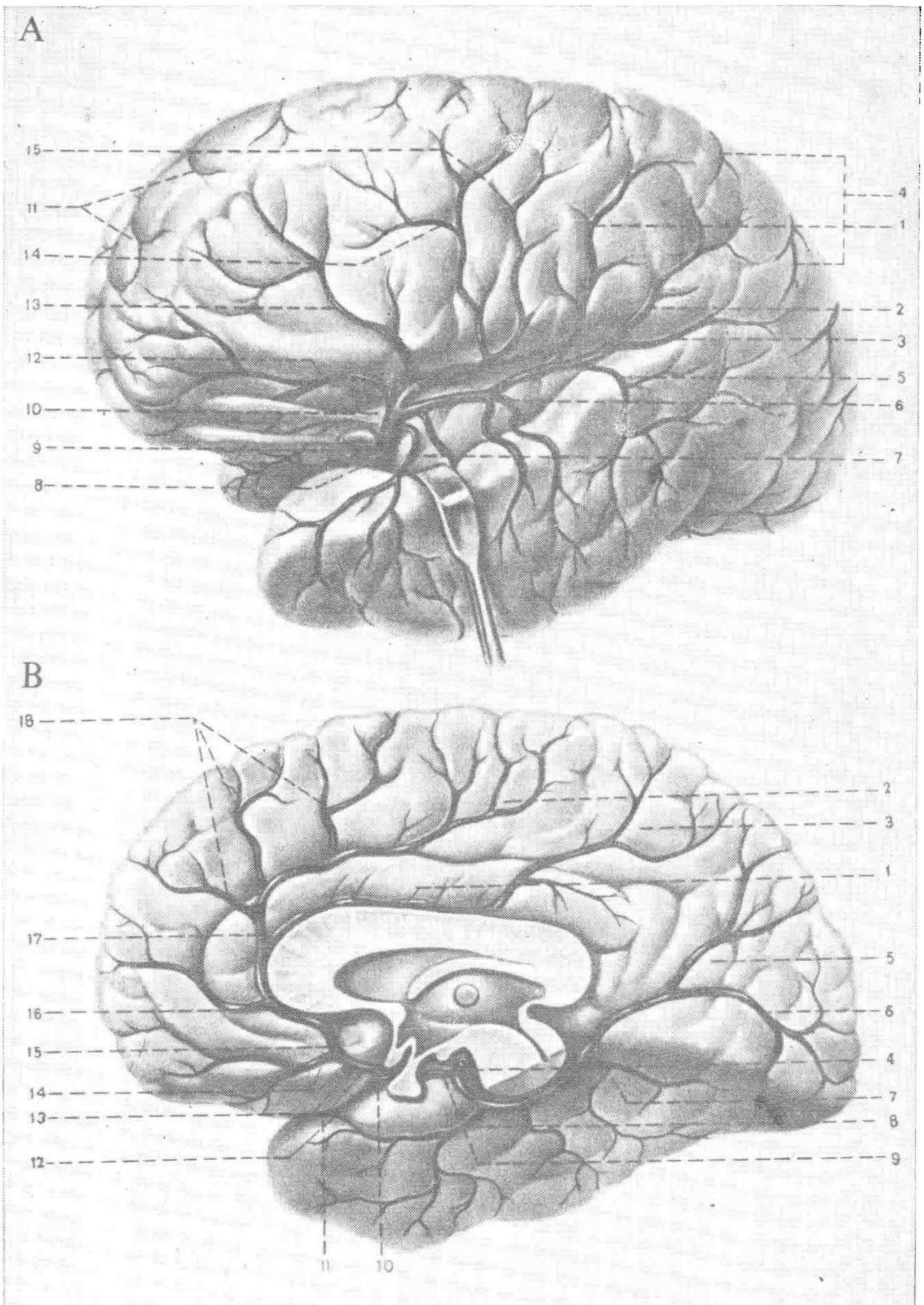
The system of arteries at the base of the brain (Fig.7), which looks like a polygon close in its shape to an oval with its larger diameter in the anterior-posterior direction, is the circle of Willis. Anatomically, it connects both systems of the carotid arteries with each other and each of them with the system of the vertebrobasilar arteries. The circle of Willis usually has its right and left sides structured symmetrically. They are composed of the cerebral segments of the internal carotid arteries, proximal segments of the anterior and posterior cerebral arteries and the posterior communicating arteries. The two halves are connected by the anterior communicating artery at the front, and by the oral portion of the basilar artery at the back.

1.4. The Arterial System of the Brain

The vessels in the base of the brain (Fig. 8), as well as the original segments of the cerebral arteries, immediately after the point of their origination give off a number of branches, the intracerebral arteries, which supply the deep-lying parts of the brain, mainly the subcortex formations. Further, the cerebral arteries run up to the surface of the hemispheres. Branching widely and making anastomoses, they form the surface vascular network, from which another group of branches leaves—the intracerebral arteries. These both groups of arteries, the one from the base of the brain, the other from its surface, converge to the centre of the brain radially, coming as if to meet each other.

The arterial system of the brain stem is a continuous network due to a large number of anastomoses. The network includes branches of both basilar and vertebral arteries. Numerous paramedian arteries supply the anteromedial portions of the brain stem, while the short and long circumflex arteries supply its lateral and posterior parts. Finally within the brain tissues the blood goes through the functional units of microcirculation: arterioles, precapillary arterioles, capillaries, postcapillary venules, and venules.

The cerebral arteries and their branches (Fig. 9) cover the surface of the brain in the arachnoid mater; alveoli, canals, and cisterns of the arachnoid are filled with cerebrospinal fluid. The arteries run through canals containing cerebrospinal fluid and are attached by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means of special cords—specific fibrous structures fixing position of the arteries. Periarterial spaces filled with spinal fluid are preserved not only on the surface of the brain, but in its deep parts as well. When arteries go deep into the brain matter, they carry with them the internal layer of the arachnoid mater (the pial infundibulum) and enter the brain surrounded by it.

The brain areas, which are vascularized by the border zones of the neighbouring arterial basins and their anastomoses, form the zones of contiguous circulation. They turn to be the most susceptible to the disturbances of cerebral haemodynamics which are triggered by the mechanism of cerebrovascular insufficiency.

The cerebral arteries, like the vessels of the base of the brain, are the arteries of the muscular type. Together with their branches and anastomoses, they are capable of active change of their lumina, and therefore take part in the regulation of both general inflow of blood into the brain and its further redistribution.

The intracerebral arteries stem from the arterial network of the surface of the brain and form the intracerebral vascular system. Short arteries supply the cortex, long ones supply the underlying white matter up to the periventricular areas. There are practically no arterio-arterial anastomoses there. The branches of the intracerebral arteries connect abundantly only at the level of their subdivision into capillaries. Therefore, the vascular network of the brain matter consists only of the capillary network with its specific metabolic function. It is not supposed to carry out collateral circulation. Hence the intracerebral arteries are usually considered to be of the functional end-artery type.

Structurally, the intracerebral arteries and their branches are of the muscular type. There are clumps of muscular cells, forming thickened 'sleeves' in the initial parts of the vessels and at the site of their branching, which are situated singularly or like beads. These formations are sphincters or 'taps' which may reduce or 'turn off'

Fig. 9. The arteries of the surface of the brain (according to Jackson, 1966).

A, facies superolateralis: *1*—r. parietalis anterior of a. cerebri media; *2*—r. parietalis posterior of a. cerebri media; *3*—a. gyri angularis, *4*—rr. terminales of a. cerebri posterior; *5*—r. temporalis posterior of a. cerebri media; *6*—r. temporalis intermedius of a. cerebri media; *7*—r. temporalis anterior of a cerebri media; *8*—a. carotis interna; *9*—a. cerebri anterior sinistra; *10*—a. cerebri media sinistra; *11*—r. terminalis of a. cerebri anterior; *12*—r. orbitofrontalis of a. cerebri media; *13*—r. frontalis; *14*—r. precentralis; *15*—r. centralis of a. cerebri media; *B*, facies medialis: *1*—r. pericallosa of a. cerebri anterior; *2*—r. paracentralis of a. cerebri anterior; *3*—r. precunealis of a. cerebri anterior; *4*—a. cerebri posterior dextra; *5*—r. parieto-occipitalis of a. cerebri posterior; *6*—r. calcarinus of a. cerebri posterior; *7*—r. temporalis posterior of a. cerebri posterior; *8*—a. communicans anterior; *9*—a. communicans posterior; *10*—a. carotis interna; *11*—a. cerebri anterior sinistra; *12*—r. recurrens of a. cerebri anterior; *13*—a. communicans anterior; *14*—rr. orbitales of a. cerebri anterior; *15*—a. cerebri anterior dextra; *16*—r. of anterior cerebral artery to frontal pole; *17*—r. callosomarginalis of a. cerebri anterior; *18*—rr. frontales mediales of a. cerebri anterior

the blood flow in some parts of the vascular system. The intracerebral arteries also have well-developed nervous apparatus, including both afferent and efferent fibres.

Arterioles of the brain have thinner walls than in any other organ. Brain capillaries consist of the endothelium and the basal membrane, composed of the membranes of the surrounding nerve elements, and they are represented with different density in different parts of the brain. There is a correspondence between the density of the cellular and glial elements, as well as peculiarities of their branching, on the one hand, and the density of the capillaries, on the other.

1.5. The Venous System of the Brain

The venous and arterial systems of the brain are connected through the capillaries only. The structural units of the cerebral venous system are: the postcapillary venules, venules, cerebral veins, venous sinuses, and major veins. The blood from the postcapillary network is collected into the veins, which form two venous systems of various localization—the systems of the superficial and deep veins of the brain.

The system of the superficial veins appears to be a network in the arachnoid mater of the hemispheres. It receives the bulk of the blood from the cortex and white matter. From it the blood is mainly drained through the sinuses of the dura mater (Fig. 10). The system of the deep veins is situated in the brain matter and is in fact a group of venous trunks, collecting blood from the transparent septum, plexuses and walls of the lateral cerebral ventricles, subcortical ganglia, thalami and other parts of the brain stem, including the cerebellum. Symmetrical internal cerebral veins join to form the great cerebral vein (i.e. Galen's great vein). It receives a number of tributaries and finally drains into the direct sinus, which is the major collector of the venous blood draining from the system of the deep veins.

One may also distinguish brain areas considered to be contiguous for venous outflow. There are numerous connections between the systems of the superficial and deep veins. There are also anastomoses between the sinuses—large venous trunks on the surface of the hemisphere, connecting the separate venous sinuses. There are also emissaries through which the cerebral venous system communicates with the external venous network of the cranium.

The bulk of the blood (two thirds) from the both systems of superficial and deep veins outflows through the venous sinuses into the

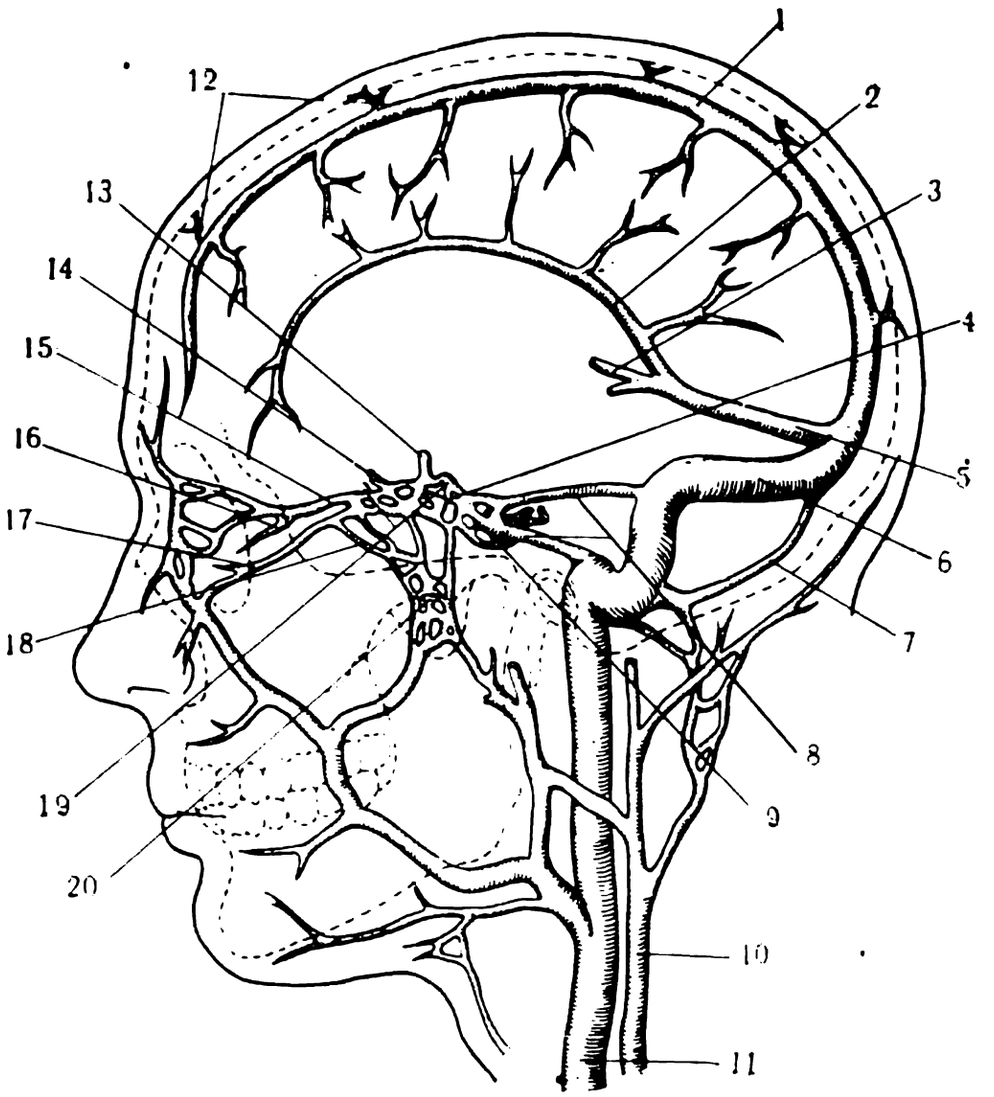


Fig. 10. Diagrammatic representation of the veins and venous sinuses of the dura mater.

1—superior sagittal sinus; *2*—inferior sagittal sinus; *3*—great vein (Galen's vein); *4*—cavernous sinus; *5*—straight sinus; *6*—transverse sinus; *7*—occipital sinus; *8*—superior and inferior petrosal sinuses; *9*—basal sinus; *10*—external jugular vein; *11*—internal jugular vein; *12*—emissaries; *13*—intercavernous sinus; *14*—circular sinus; *15*—common ophthalmic vein; *16*—central vein of the retina; *17*—inferior ophthalmic vein; *18*—superior ophthalmic vein; *19*—pterygoid parietal vein; *20*—pterygoid plexus

internal jugular vein, while about one third of the blood drains through the paracranial venous plexuses into the external jugular vein.

Venous sinuses are specific elements of the cerebral venous structure; they are the major pathways carrying blood from the brain. They are formed by the duplicature of the dura mater, which prevents them from compression. Cerebral veins are provided with very thin walls having one or two layers of endothelium and a layer of connective tissue. The venous system of the brain has a well-developed nervous apparatus, including baroreceptors and possibly chemoreceptors as well.

1.6. The Sources of Blood Supply to Various Areas of the Brain

The sources of blood supply to the cortex and white matter are the anterior and middle cerebral arteries of the carotid system and posterior cerebral arteries of the vertebrobasilar system (Fig. 11). The cortex of the internal surface of the hemispheres is supplied mainly by the anterior cerebral artery, the cortex of their convex surface by the middle cerebral artery, and that of their basal surface—by the posterior cerebral artery. Branches of the anterior cerebral artery pass over to the anterior superior part of the convex surface and to the anterior part of the basal surface; branches of the posterior cerebral artery run over to the posterior parts of the internal and the convex surface of the hemispheres. The branches of the anterior and posterior cerebral arteries both prior and after their passage over the corresponding edges of the hemispheres to other parts of the brain surface form anastomoses between themselves, and after they pass over to the convex surface of the hemispheres they form anastomoses with the branches of the middle cerebral artery.

The most important areas of the white matter are supplied by the following arteries: the corpus callosum by the anterior and posterior cerebral arteries, the internal capsule by the anterior, middle, posterior cerebral arteries and the anterior artery of the vascular plexus, the optic radiation by the posterior and middle cerebral arteries.

The subcortical ganglia (the caudate nucleus, putamen, and globus pallidus) are supplied from the striatal arteries, which originate from the main branches of the internal carotid artery, i.e. the anterior and middle cerebral arteries and the anterior artery of the vascular plexus.

The thalamus is supplied by the both cerebral arterial systems—carotid and vertebrobasilar. The pertinent arteries originate from the posterior communicating artery and the anterior artery of the vascular plexus, as well as from the posterior cerebral artery.

The midbrain (Fig. 12), pons (Fig. 13) and medulla oblongata (Fig. 14) are supplied by numerous arteries which are either branches of the vertebral and basilar arteries proper, or their large branches (i.e. posterior cerebral and cerebellar arteries).

The cerebellum (Fig. 15) is supplied by three pairs of the cerebellar arteries, originating from the basilar and vertebral arteries; they anastomose abundantly on its surface.

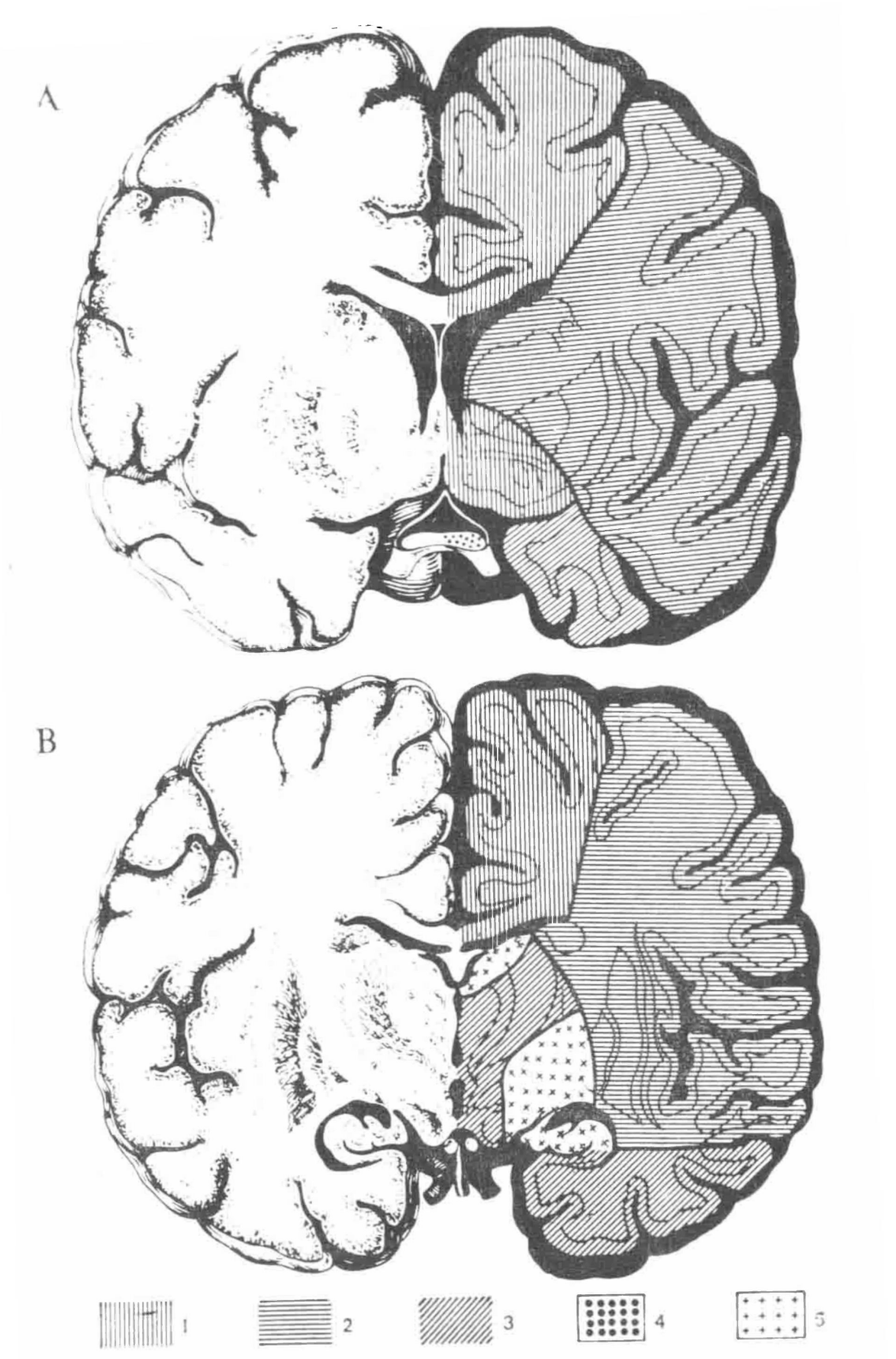


Fig. 11. Diagrammatic representation of blood supply to the cerebral hemispheres (according to Hiller, 1936).

A, frontal section on the level of pronounced subcortical ganglia; *B*, frontal section on the level of the nuclei of the thalami; arteries of the end-brain: *1*—a. cerebri anterior; *2*—a. cerebri media; *3*—a. cerebri posterior; *4*—a. communicans posterior cerebri; *5*—a. choroidea anterior

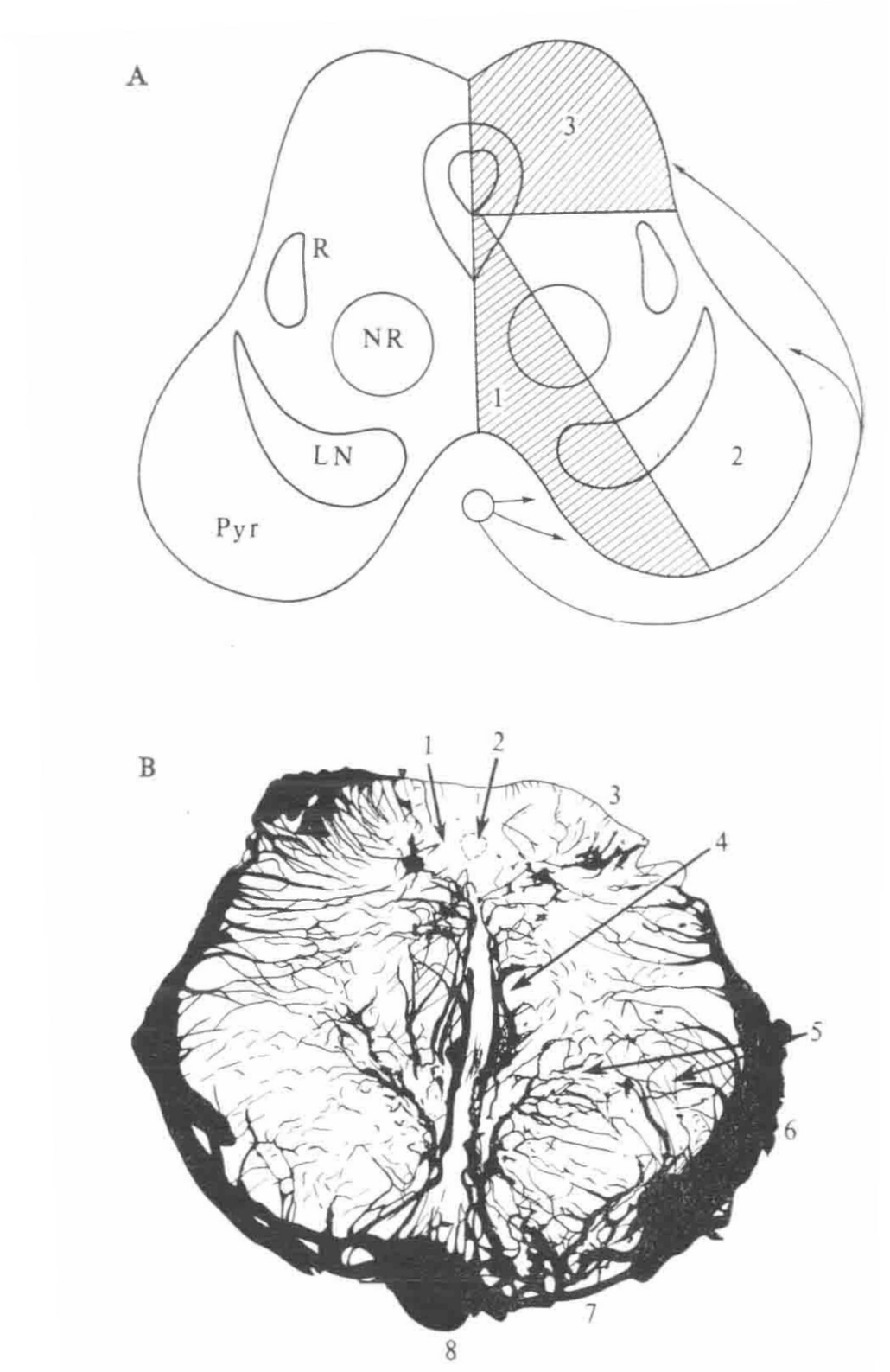


Fig. 12. Diagrammatic representation of the blood supply to the midbrain.

A, according to Foix and Hillemand, 1926:

1—area of the paramedian arteries; *2*—area of the short circumflex arteries; *3*—area of the long circumflex arteries; Pyr—pyramidal tract; LN—black substance; NR—red nucleus; R—medial loop

B, a section through the caudal end of the mesencephalon which illustrates the distribution of the deep nuclear perforators (according to Kaplan and Ford, 1966):

1—substantia grisea centralis with small arterial branches; *2*—aqueductus cerebri; *3*—tectum mesencephali; *4*—centromedial perforators from the a. basilaris; *5*—perforators to the region of the substantia nigra arising from the quadrigeminal branch of a. mesencephalica; *6*—segment of a. cerebelli superior overlying r. indicated in *7*; *7*—rr. of the tectum mesencephali from the a. mesencephalica; *8*—a. basilaris

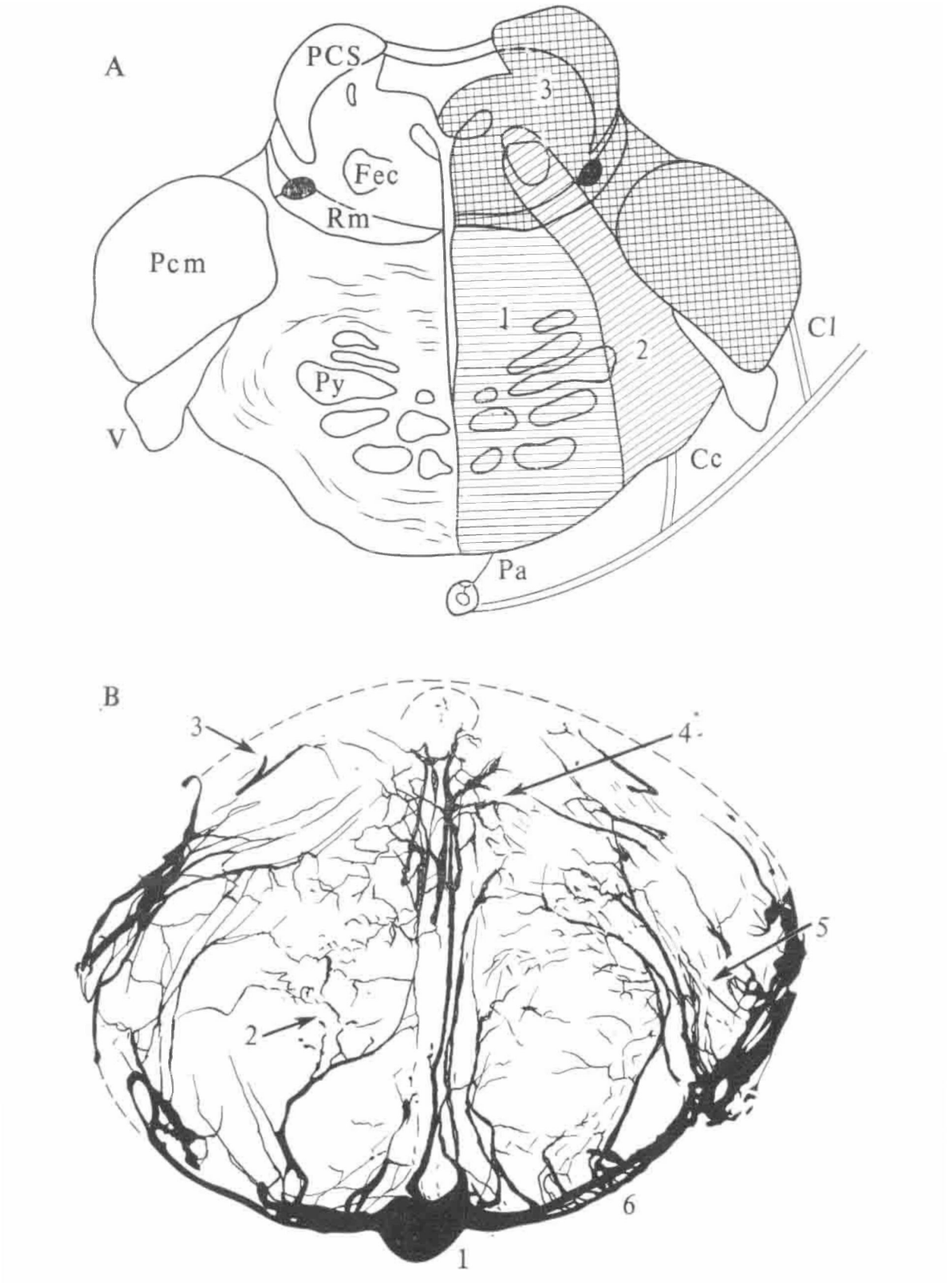


Fig. 13. Diagrammatic representation of the blood supply to the pons.

A, according to Foix and Hillemand, 1925:

Pa—paramedian arteries and their area (*1*); Cc—short circumflex arteries and their area (*2*); Cl—long circumflex arteries and their area (*3*): Py—pyramidal tract; Pcm—middle cerebellar peduncle; V—trigeminal nerve; Rm—medial loop; Fec—central tegmental tract; Pcs—superior cerebellar peduncle. *B*, a section through the rostral end of the pons which illustrates the distribution of the perforators to the deep nuclear masses (according to Kaplan and Ford, 1966): *1*—a. basilaris; *2*—large perforator to the pontine nuclei; *3*—pedunculus cerebellaris superior; *4*—large medial perforators to the tegmentum pontis; *5*—large lateral perforators; *6*—rr. to pontem

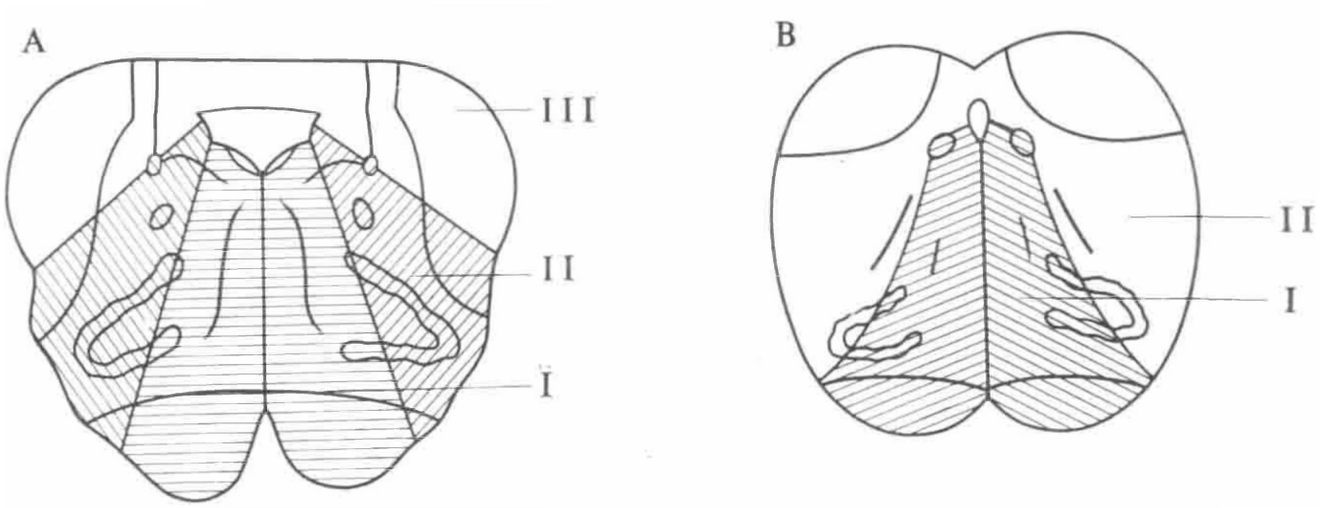


Fig. 14. Diagrammatic representation of the blood supply to the medulla oblongata (according to Foix and Hillemand, 1926).

A—middle portion; *B*—lower portion; *I*—area of the paramedian arteries; *II*—area of the vertebral arteries; *III*—area of the posterior inferior cerebellar artery

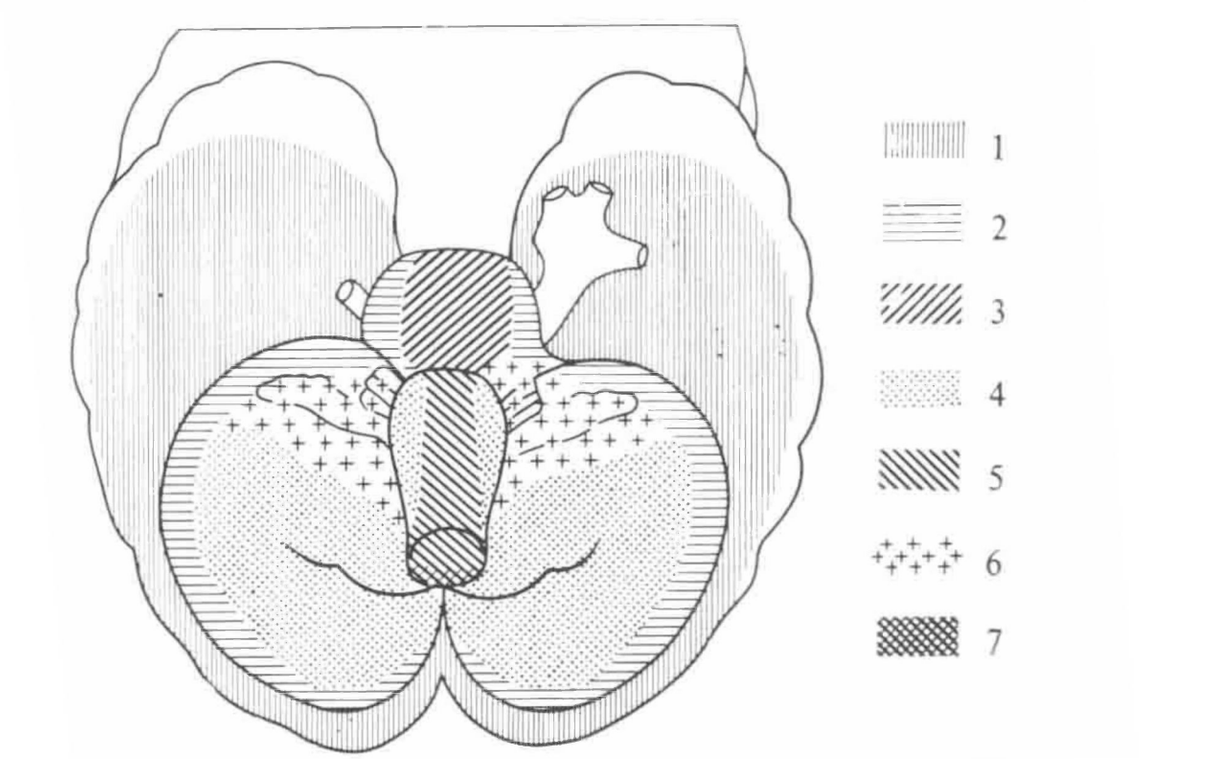


Fig. 15. Diagrammatic representation of the blood supply to the cerebellum, brain stem, and occipital lobes of the brain (according to Krayenbühl and Yasargil, 1957).

1—a. cerebralis posterior; *2*—a. cerebellaris superior; *3*—aa. paramedianae of a. basilaris; *4*—a. cerebellaris inferior posterior; *5*—a. spinalis anterior and aa. paramedianae of a. vertebralis; *6*—a. cerebellaris inferior anterior; *7*—a. spinalis dorsalis

1.7. Regulation of Cerebral Circulation

Modern concepts of regulation of cerebral circulation basically admit certain autonomy of the cerebral circulation itself, existence of diversified system of its regulation, including the extracranial level, as well as existence of autoregulation, operating within certain limits, and its multiple functional mechanisms. Various parts of the cerebrovascular system differ not only in their anatomy, but also in the functional structure and role in regulation of cerebral circulation.

Normal functioning of the system of regulation of cerebral circulation is possible only within certain limits of systemic arterial pressure, the minimal (critical) level of which is assumed to be 60 mm Hg. The principal reflexogenic zone signalling the changes in it and triggering the cerebral mechanisms for their correction is localized in the aortic arch. At the same time there is an apparatus (the carotid sinus) in the original parts of internal carotids, maintaining a necessary level of both systemic arterial pressure and the pressure in the major arteries of the head.

The major arteries of the head take part in regulation of the inflow of blood to the circle of Willis and to other cerebral vessels by means of variation of their lumina. The anatomical basis for the mechanism of the vasoconstriction reactions is the powerful muscular layer and rich innervation present in the precranial portions of the carotid and vertebral arteries. The major arteries of the head narrow in response to a rise in arterial pressure, venous congestion, and cerebral oedema. Physiologically, the point of such a response is to limit the inflow of blood into the cerebrovascular system. The arteries dilate when the arterial pressure drops. The inflow is also regulated by such parts of the major arteries of the head, as those in the cavernous and atlanto-occipital sinuses. A rise in venous pressure in the sinuses triggers reduction in the inflow of blood to the brain in the carotid and vertebral arteries. Besides, the physiological curves of these arteries also help smooth out the blood flow reducing the pulse and other variations of arterial pressure.

The major arteries of the head regulate the blood inflow to the brain as a common functional system. Its function is to provide both constant blood supply to the brain and relative independence of the supply from changes in the general circulation. That means control of a number of unfavourable factors influencing cerebral circulation, such as variations in systemic arterial pressure, inadequacy between the inflow and outflow of blood in the vascular system, etc.

Other mechanisms are responsible for regulation of adequate blood supply to the brain, i.e. provision of delivery of blood to the function-

ally active areas of the brain in compliance with their metabolic demand, at the level of the system of cerebral and intracerebral arteries. The structure of the cerebral arteries (their muscular layer) provides the possibility to vary their lumina in a wide range, and control of the vascular network on the surface of the brain allows timely directing the necessary volume of blood to the parts of brain with heightened neuronal activity.

The system of regulation of adequate cerebral blood flow is complicated. The presently known mechanisms of its regulation are myogenic, neurogenic, neurohumoral, and metabolic ones. The effectors are the smooth muscles of cerebral vessels, whose contraction or relaxation causes constriction or dilatation of their lumina. The pathways along which information on the demands of the functioning areas of the brain is transmitted to the vessels have been studied insufficiently. The most fully developed concepts are those of the myogenic and metabolic mechanisms of the blood flow regulation. The latter is considered especially important.

The myogenic regulation of cerebral blood flow is effected due to change in intra-arterial pressure through a direct response of the muscles of the vessel walls—constriction of the arteries with the rise of the pressure and their dilatation with its drop (the Ostroumov-Bayliss phenomenon). The time period of this response is short. It is limited by correction of small variations of intra-arterial pressure.

The phenomenon occurs when the mechanisms of the extracranial level, smoothing out variations of arterial pressure, do not suffice. It is followed then by the mechanism of metabolic regulation which is assumed to be the main one, determining the condition of cerebral blood flow. An increase in the functional activity of nerve cells is accompanied with a gain in their consumption of oxygen, which decreases its tension in the brain matter and increases accumulation of carbon dioxide there (hypercapnia). This causes a shift in the acid-base balance into the acid direction (acidosis), a drop of pH in the intercellular fluid (normally 7.35-7.45), which results in dilatation of cerebral arteries and a rise in the inflow of blood to the active area of the brain. Enhancement of local cerebral blood flow improves the delivery of oxygen, removal of excess carbon dioxide and restoration of the normal pH value, due to which the arteries narrow and the parameters of the blood flow are reestablished. Thus, the influence of carbon dioxide, one of the metabolic end-products in the brain, is exerted indirectly, as a result of the shift of pH, the necessary requirement for that being sufficient concentration of potassium ions in the blood. Inhalation of carbon dioxide also causes improvement of cerebral blood flow, which is applied therapeutically. Hence, a shift in carbon dioxide content in the brain matter is the main triggering mechanism of the metabolic regulation of cerebral circu-

lation. It is characteristic for this kind of regulation that it has the benefit of both high rate of the metabolic processes involved and fast adjustability of local haemodynamics to the ever changing demands of the brain.

The role of the nervous system in regulation of cerebral circulation is not to be doubted. The major arteries of the head, as well as cerebral and intracerebral arteries, are all supplied with neural plexuses, having both sympathetic and parasympathetic fibres. The receptor apparatus is also rich in individual nerve cells, including the unipolar ones, which are localized along the cerebral vessels and in the soft arachnoid meninx. Some of them supposedly take part in local reflexes, providing for the necessary redistribution of blood, and others participate in local regulation and co-ordination of the metabolic processes. Receptor reflexogenic zones have been found both in the arteries and veins: in the carotid and cavernous sinuses, cerebellomedullary cistern, great cerebral vein and internal jugular vein.

Thus, neural control of the vasomotor activity of the multi-level cerebrovascular system exists along with metabolic control. Various parts of the cerebrovascular system are highly sensitive not only to nervous, but to humoral influence as well. And it is not uncommon that the response of the cerebral arteries differs from the response of other parts of the organism's vascular system, both quantitatively and qualitatively.

1.8. Autoregulation of Cerebral Circulation

Physiological mechanisms, both local (myogenic and metabolic) and general (neurogenic and neurohumoral), provide for adequate cerebral blood flow when systemic or regional arterial pressure varies or when there are local metabolic shifts or other factors influencing the cerebrovascular system. The capacity of these mechanisms to maintain cerebral blood supply in compliance with its functional and metabolic demand, and thus ensure relative stability of the inner medium (i.e. homeostasis) has been called autoregulation of cerebral circulation.

Autoregulation of cerebral blood flow is possible only within certain range, limited with the critical values of the factors triggering the mechanisms of autoregulation. These are: the level of systemic arterial pressure, the value of oxygen tension, carbon dioxide tension, pH of the brain matter, etc. Thus, autoregulation of cerebral circulation usually falls beyond the following limits of systolic pressure: under 80 and over 180 mm Hg. The minimal value of the

critical level of systemic arterial pressure is assumed to be 60 mm Hg, the initial level being 120 mm Hg. At a lower level, autoregulation fails and cerebral blood flow depends upon systemic arterial pressure, directly following its change.

It has been very important for the clinical practice to establish the influence of the initial level of systemic arterial pressure in this respect, and particularly the range within which cerebral blood flow remains stable. The ratio of that range to the initial level of pressure (the index of autoregulation of cerebral circulation) shows to a certain extent the potential possibility of autoregulation. Autoregulation also fails at a certain rate of decrease of systemic arterial pressure which is important for clinical practice.

The autoregulation index may be very low in patients with cerebrovascular diseases. That means that even a small drop of high enough arterial pressure may still cause cerebral ischaemia.

Autoregulation may fail as well when arterial pressure increases considerably. This is the case when myogenic regulation breaks down, since the muscular lining of the arteries cannot withstand the raised intravascular pressure. Consequently the arteries dilate and the blood flow increases. But then the walls of the vessels begin to change causing cerebral oedema with a following sharp decrease in the cerebral blood flow despite the level of systemic arterial pressure is still high. This mechanism of successive changes in cerebral blood flow may underlie hypertensive crises.

Autoregulation may also fail when the metabolic control of cerebral blood flow is insufficient. Accumulation of carbon dioxide in the brain matter and related shift of pH in the intercellular fluid are among important factors of cerebral blood flow regulation. Sometimes, i.g. after return of the blood flow back to normal in a previously ischaemized area of the brain, carbon dioxide concentration usually falls, but pH value is still low because of metabolic acidosis (partially due to accumulation of lactic acid in the brain). As a result, the vessels are dilated and cerebral blood flow remains abundant exceeding the initial level in spite of the current lack of functional demand. Oxygen is not fully utilized, and the outflowing venous blood is of a red colour. This condition is called the luxury perfusion syndrome, first described by Lassen (1965). This is the case when metabolic mechanism of cerebral blood flow autoregulation is disturbed.

Autoregulation is also impaired due to decrease of saturation of blood with oxygen or to increase of carbon dioxide tension in the brain. Changes in cerebral blood flow in such cases also directly follow those of systemic arterial pressure.

Metabolic disturbances, and hence blood flow regulation impairment, may be of a local character, e.g. in focal brain lesions with reactive hyperaemia in the affected area. Response of the arteries to

both vasodilative or vasoconstrictive influences in the focus of lesion is either lost or sharply reduced. It remains nevertheless normal in the healthy areas of the brain. Active change of circulation occurs therefore only in the healthy areas of the brain with preserved vessel reactivity, while the response is passive in the focus of lesion. Consequently vasodilative factors result in enhanced inflow of blood only into the healthy areas of the brain, including transfer of blood from the affected area, and hence to the detriment of its own supply. This phenomenon is called the syndrome of intracerebral 'stealing'. On the contrary, vasoconstrictive factors, lessening the supply of the healthy areas around the affected focus, help redistribute blood to the benefit of the focus of lesion. This is the perverted phenomenon of intracerebral 'steal syndrome', or the 'Robin Hood syndrome'.

Thus, cerebral blood flow is capable of autoregulation when the conditions for the brain are normal. The possibilities of autoregulation of the brain may be limited in a cerebral lesion or oedema, insufficiency of brain blood supply due to impairment of the patency or innervation of the cerebrovascular system, unfavourable change in blood content, etc.

1.9. Collateral Circulation in the Brain

Collateral circulation is extremely important for ensuring compensatory mechanisms in the cerebrovascular system. The consequences of obstruction of cerebral arteries depend mainly on the possibilities of collateral blood supply, which are determined in their turn by many factors. Due to peculiarities of the structure of the cerebrovascular system, four anatomical levels of collateral circulation are distinguished: one extracranial and three intracranial levels.

The extracranial level of cerebral collateral circulation is a group of anastomoses between the systems of the carotid and vertebrosubclavian arteries. The most important anastomoses are: between the occipital artery (a branch of the external carotid) and the muscular branches of the vertebral artery, between the occipital artery and the arteries of cervicothyroid and costocervical trunks (branches of the subclavian artery), between the superior thyroid arteries (branches of the external carotid) and the inferior thyroid arteries (branches of the subclavian artery). The last-mentioned anastomosis also connects the systems of the carotid and subclavian arteries of the both sides. Both external carotids are connected as well with the lingual and external maxillary arteries. These anastomoses ensure collateral circulation when the vertebral and common carotid arteries are occluded.

The intracranial levels of cerebral collateral circulation are represented by the following three groups of anastomoses: the circle of Willis, anastomoses between the cerebral arteries on the surface of the brain, and the intracerebral vasculocapillary network.

The circle of Willis, the most important basal anastomosis, appears to be blood redistributor. Its anterior communicating artery is the main source of blood supply to the hemisphere on the side of the occluded internal carotid or the proximal segment of the anterior cerebral artery. The posterior communicating arteries ensure circulation in occlusion of the internal carotids (especially when both arteries are occluded), as well as circulation in the opposite direction—in occlusion of the vertebral or proximal segments of the posterior cerebral arteries. On the whole, this level of anastomosis is characterized by an automatic turn-on of the communicating arteries with a turn-off of one of the major arteries of the head, which results in ensuring balanced blood supply to the cerebral hemispheres.

Anastomoses on the surface of the brain, between the anterior, middle, and posterior cerebral arteries provide favourable conditions for blood overflow in case of occlusion and consequently a drop of pressure in the basin of one of them (i.e. in a comparatively small area of the vascular system). Foci of necrosis form in areas, which lie most distally from the source of collateral circulation, when there is insufficiency of blood inflow through anastomoses. In insufficiency of brain circulation on the whole blood flow in the areas supplied by these anastomoses sharply reduces, since they are the most distal from the source of blood supply. The same holds for the long intracerebral arteries perforating the brain matter. The white matter and the areas of contiguous circulation of the cortex suffer in such cases, because they are supplied with distal, peripheral branches.

There are a number of other anastomoses. In occlusion of the internal carotid, the most important of them appears to be the direct intra-extracranial anastomosis of one of its branches, the ophthalmic artery, with the branches of the external carotid in the area of the forehead, the ridge of the nose, and the angle of the eye. The branches of the ophthalmic and middle cerebral arteries have been found to anastomose with the arteries of the dura mater. Anastomoses of the cerebellum play the role of collaterals in occlusion of the basilar artery. Anastomoses on the surface of the brain stem or the spinal cord are poorly developed. Therefore the possibility for blood redistribution is limited there. Anastomoses of intracerebral arteries are more important for that.

As to anastomoses of the intracerebral vasculocapillary network, their role for collateral circulation in the other areas of the brain in case of occlusion of the brain arteries is insignificant.

It has been found that there are stages in the development of collateral circulation in the brain. The acute stage of diffuse dilatation of vessels is followed by the chronic stage of development of certain collateral pathways, and certain normalization of the condition of the vessels in the other parts of the basin of the occluded artery. Collateral circulation thus established may turn out at that to be very different in volume—from luxury perfusion to reduced blood flow. That leads to marked functional and structural change in the arterial walls. Earlier these changes were regarded as arteritis of obscure aetiology (the cerebral form of Winiwarter-Buerger disease), while they may appear as a secondary response of the arteries to the changed condition of circulation. It has been established as well that reduced circulation may stimulate formation of microemboli out of blood elements. It is known now that there is a possibility for reverse development of the changes in the vessels, caused by cessation or slowing down of blood flow (thrombosis, recalibration of arteries), and for re-establishment of their lumina.

The chance to develop adequate collateral circulation depends on a number of factors, the most significant being the state of the pathways for collateral and general circulation. It is important to bear in mind that when cerebral vessels are being occluded, the process of triggering the complex mechanisms for compensation of disturbed circulation takes some time. Therefore realization of potential collateral circulation is certainly related to the rate of the development of occlusion. When the rate of the process of blocking the vessel lumen is high (embolism), focal changes in the brain occur in every case, regardless of the point of occlusion. It is natural, though, that the range of the consequences may be different depending on many other factors. When the rate of occlusion of a vessel is relatively low, localization and the size of the affected brain substance, other conditions being equal, are both determined by the localization of the artery occlusion, in particular by its relation to the circle of Willis.

The most unfavourable to potential collateral circulation is occlusion of the arteries within the circle of Willis or more distally from it, e.g. thrombosis of the intracranial segment of the internal carotid artery with extension of the thrombus into the circle of Willis, since that eliminates the possibility of blood supply into the vessels of the hemisphere on the side of occlusion from the vessels of the other hemisphere.

Grave consequences follow occlusion of the intracranial segment of the vertebral artery within the bulbar arterial circle. Clinical development in this case is intense and it is characterized by persistent focal neurological symptoms.

Patients with occlusion of the intracranial segment of the carotid artery most commonly die of oedema, and swelling of the brain due

to extensive foci of necrosis of cerebral matter. Bilateral occlusion of the intracranial segments of the vertebral arteries is almost always fatal, even when their occlusion proceeds gradually for a long time period. Conversely, occlusion of the carotid outside the cranium (more proximally than the circle of Willis) may not uncommonly be asymptomatic, as well as occlusion of only one vertebral artery.

As to occlusion of the cerebral arteries, blood flow there has been considered insufficient for adequate collateral circulation in spite of the wide network of anastomoses. There is a growing number of observations confirmed by angiograms, in which occlusion of the middle cerebral artery is accompanied with minimum of neurological symptoms. The angiograms register the arterial basin filled with the contrast agent from the neighbouring areas.

Normal condition of the mechanisms of autoregulation of cerebral circulation is very important for ensuring full-value collateral circulation. However, they are not uncommonly unstable in patients with cerebrovascular diseases. Because of that their cerebral blood flow depends more heavily on the condition of general circulation and other extracerebral factors.

Generalizing the data on factors promoting or preventing the development of sufficient compensatory circulation and thus determining the consequences of occlusion of cerebral arteries, one may mark the following. Above all, there are structural peculiarities, both typical and individual, of certain regions of the cerebrovascular system. Apart from the features of angioarchitectonics, these are the number and size of the anastomoses and their proximity to the areas within the basin of the occluded artery. Other factors are patency of the vessels providing collateral blood flow, and the level of systemic arterial pressure (including initial). Thus, in case occlusion of an artery develops on a background of some previous occlusions of the major vessels, it is natural that the compensatory blood flow is going to be more limited. The rate of the occlusive process should also be taken into account.

Under certain conditions the general pattern of collateral circulation is not substantiated physiologically. Such a peculiar mechanism of disturbances of cerebral circulation occurs in occlusion of the proximal segments of the branches of the aortic arch (the subclavian, innominate and common carotid arteries); it is called the steal syndrome. It has been described first in occlusion of the initial segment of the subclavian artery and has been named the subclavian steal syndrome. In this case the vertebral artery on the side of occlusion is functioning with regard to the arm as a collateral in which blood flows in a retrograde direction from the vertebrobasilar system into the arterial system of the arm to the detriment of the brain. If the arm is exercised intensely, the inflow of blood to the brain becomes less (because of 'stealing'), which causes the brain-stem symptoms.

It has been found that there are other ways of blood outflow, which are governed by similar mechanisms, e.g. blood flows out from the same system through anastomoses with the ascending and deep cervical arteries (a variant of the subclavian steal syndrome). It occurs in combined occlusion of the proximal segments of the subclavian and vertebral arteries. Since the branches of the aortic arch are often affected, one should take into account in neurological practice the possibility of a negative influence on cerebral haemodynamics of the 'perverted' blood flow in the pathways of collateral circulation on the extracranial level. It is likely that the phenomenon is of universal nature, and it should be considered in evaluating collateral circulation both for the whole brain and for its individual portions.

Chapter 2. The Early and Pronounced Manifestations of Insufficiency of Cerebral Circulation

2.1. Pathogenesis

Cerebrovascular diseases cause inadequacy of the volume of blood inflow to the demand of the brain tissue and the development of acute and chronic insufficiency of cerebral circulation with diffuse and focal neurological disturbances.

The pathogenesis of insufficiency of brain circulation is underlain by various dysfunctions: (1) disturbances of neural regulation of cerebral vessels; (2) morphological changes in the vessels, causing decreased patency of brain arteries; (3) insufficiency of collateral circulation; (4) impairment of the autoregulation of brain circulation; (5) disorders of general haemodynamics; (6) changes in biochemical and physicochemical blood properties; (7) insufficiency of coronary circulation. The pathogenesis of insufficiency of cerebral circulation usually includes several factors.

At the early stage of cerebrovascular diseases there are some diffuse changes in the structure and function of nerve cells, as well as hardly noticeable disturbances in higher cortical function, psyche, sensitivity and the organs of sense, in coordination, motor and other kinds of activity. Disturbances of vegetovascular function become apparent in some physical and mental overstrain, agitation, and stress. Then circulatory disorders develop (ischaemic lacunar process) which cause formation of cysts in the cortex of cerebral hemispheres, subcortex, brain stem; paroxysmal or sometimes stable hyperkinesia, 'late' epilepsy, signs of parkinsonism, and pseudobulbar symptoms occur. At the advanced stage of the disease, local, multifocal or extensive ischaemic softenings develop (ischaemic cerebral infarctions) and sometimes haemorrhagic and mixed infarctions or cerebrocardiac disturbances.

2.2. Clinical Picture

Insufficiency of brain blood supply is characterized by the following: (1) recurring dyscirculatory phenomena; (2) diffuse motor disor-

der, synkinesia, hyperkinesia, change in the muscle tone, coordination disturbances, etc.; (3) cerebrovascular paroxysms: vestibular disorders, syncopes, short periods of unconsciousness, disturbances of the cortical function, etc.

There are several stages which may be observed in insufficiency of cerebral circulation: **latent (subclinical) stage, early manifestations of insufficiency of cerebral circulation and pronounced symptoms of cerebrovascular pathology (dyscirculatory encephalopathy).**

Patients with **early manifestations of insufficiency of cerebral circulation** show different signs of a general vascular disease, predominantly atherosclerosis, hypertensive disease, or vegetovascular dystonia (dysfunction).

The concept of **vegetovascular dystonia** covers temporary and reversible vegetovascular disturbances due to complicated neurochemical humoral disorders, changes of colloid equilibrium, features of hormonal activity, or the organism's specific reactivity. Vegetovascular dysfunction depends on some neurodynamic changes in the central nervous system, particularly in the cerebral cortex and the reticulolimbic complex. Cholinergic and adrenergic substances, involved in transmission of stimulation in the central nervous system, affect reflex processes in the brain. Making a diagnosis of vegetovascular dystonia, one should establish its aetiology: infection, intoxication, trauma, disease of the endocrine glands, neurosis, allergization, drug intolerance, the pathology of labour and pregnancy, congenital personality traits. **Vegetative instability** may sometimes be observed since childhood, which occasionally becomes more pronounced owing to some unfavourable environmental influences. It is compensated under favourable conditions and reappears with worsening in the organism's general condition, especially with the development of neuroses. Vegetative instability manifests itself from time to time in cardiovascular paroxysms or vestibular disturbances. Overstrain or lability of the nervous processes may result in vegetative disorders (cephalalgia, acrospasm, etc.), when vegetative instability is observed along with unstable vascular reactions. Sometimes dynamic observation helps find out that in vegetative instability disorders may result from neuropsychic overstrain after which some trace reactions remain. Vegetovascular disturbances of sporadic nature may recur when a 'sore point' is 'touched'.

Persistent pronounced disorders of vascular tonus may give rise to development of arterial hypertension and/or atherosclerosis. Persons with latent (subclinical) insufficiency of cerebral circulation usually have no complaints. Their vegetovascular disorders appear as variations in arterial pressure, hyperhidrosis, acrocyanosis, vasomotor lability, tremor of the eyelids and fingers of stretched out arms, as well as a slight increase in tendon reflexes. Rheoencephalo-

graphy shows signs of cerebrovascular insufficiency as a rise or drop in vascular tonus, and a decrease in brain pulse blood volume.

Patients with *early manifestations of insufficiency of cerebral circulation* account for 29 per cent of out-patients with cerebrovascular abnormalities, who seek the help of neurologists, and 6 per cent of neurological in-patients.

The *early manifestations* of cerebrovascular diseases are characterized clinically by unstable *headaches*, sensation of heaviness and noise in the head, 'flickering points' before the eyes, short-term mild *vertigo*, and feeling of instability when walking. Some patients complain of sleep disturbances, rapid fatigue, weakening memory, a decrease in intellectual capacity. The signs appear more often under unfavourable conditions after physical or emotional overstrain, alcohol uptake, or under effect of weather, etc. One may observe phenomena of vegetovascular dysfunction, the neurasthenic syndrome, mild symptoms of oral automatism. Emotional instability shows in tearfulness, which may appear inadequately when hearing good news, gay music, etc.

Psychological study reveals some delay in solving intellectual problems, without qualitative slips.

Among the patients with cerebrovascular diseases those with *pronounced manifestations of cerebrovascular pathology* (dyscirculatory encephalopathy) account for 7 per cent of out-patients and 3.3 per cent of neurological in-patients.

The clinical picture of dyscirculatory encephalopathy is characterized by sharp memory disorders, considerable disturbances in emotional and volitional spheres, changes in psyche, diffuse focal neurological symptoms, the pseudobulbar and parkinsonian syndromes, and late epilepsy. Attention is reduced, new information is comprehended poorly, the field of interests becomes gradually narrowed. Such patients can perform their habitual duties, but a new stereotype is produced with difficulty and strain. It becomes difficult for them to switch over from one kind of activity to another. Dexterity in work is lost, there are errors in intellectual work; mental and physical activity becomes slow, energy and initiative are reduced. The patients grow faint-hearted, their self-criticism and interests decrease, working capacity becomes impaired. Vertigo occurs more frequently. Sometimes transient disturbances of brain circulation may occur. Repeated disorders of that kind bring about acceleration of organic changes in the brain and development of the pseudobulbar syndrome. Psychological examination reveals narrower range of comprehension, longer periods for producing associative links, and difficulties in digestion of what has already been comprehended, i.e. the qualitative aspect of remembering is affected. Pronounced sensomotor changes by the type of loss of function develop, as well as aphasia, agnosia, and apraxia. Usually there

is marked atherosclerosis in coronary and limb vessels. Atherosclerosis and pale optic disk are revealed in the fundus of the eye. Temporal arteries may be tortuous.

2.3. Methods of Study

Special techniques are used to establish more accurately diagnosis and the pathogenic mechanisms of insufficiency of brain circulation. *Ultrasound flowmetry*, based on the Doppler effect, reveals the rate and direction of blood flow in the major arteries of the head. This method helps diagnose stenosis and thrombosis in the extracranial segments of the carotid and vertebral arteries, as well as peculiarities of collateral brain circulation in occlusional lesions of the brachiocephalic arteries. Blood flow asymmetry with more than 30 per cent drop in the affected side is a sign of arterial stenosis. When an artery is occluded, collateral circulation may bring about reverse blood flow in a segment of the artery or its branches situated above the occlusion.

Rheoencephalography (REG) provides data on the tonus of brain vessels, venous outflow, organic changes in the vascular walls, the presence and nature of vertebrogenic effect on the vertebral arteries, the volume of blood flow in various brain areas, the extent of insufficiency of blood supply, and on the compensatory mechanisms. Early manifestations of cerebrovascular insufficiency may be seen in REG as prevalence of angiodystonia, in some cases there are a decrease in cerebrovascular tonus, venous hypotonia or venous congestion. Blood volume in various vascular zones is good and symmetric (Figs. 16, 17, and 18). With growing clinical manifestations of insufficiency of cerebral circulation signs of organic affection of the vessel walls may appear in REG: flattening of the curves and smoothing out of the dicrotic peak in atherosclerosis and flattening of pulse waves with an upward displacement of the dicrotic peak in hypertensive disease. Administration of vasodilatators, however, results in complete normalization of the REG pattern. There is still no clear change in the reactivity of the vessel wall. Not infrequently signs of vascular hypotension or venous congestion are observed. As a rule, blood volume in various vascular zones of the brain is still good and symmetric.

When the clinical picture is more pronounced, REG registers some changes in the elasticity of the vessel wall (considerable flattening of the pulse waves, lengthening of their ascending part and a rise in its proportion to the whole cardiac cycle). Reactivity of the vessel wall changes with prevailing hyper-reactivity, sometimes signs of angiospasm may be traced (flattening of the wave tops with an upward shifting of the dicrotic peak), especially frequently of

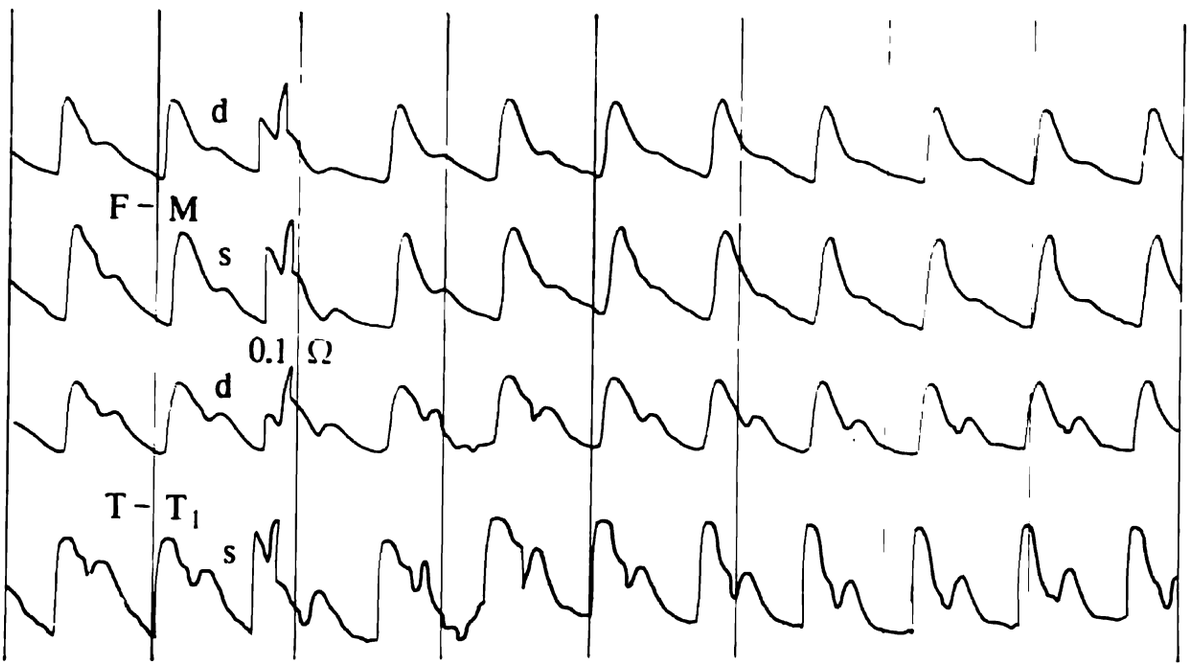


Fig. 16. REG of a male patient with arterial hypotension. The tonus of brain vessels (F-M) is considerably lower than that of extracranial vessels (a symptom of cerebrovascular insufficiency).

F-M—intracranial carotid areas; T-T_1—extracranial carotid zones; *d*—right side; *s*—left side

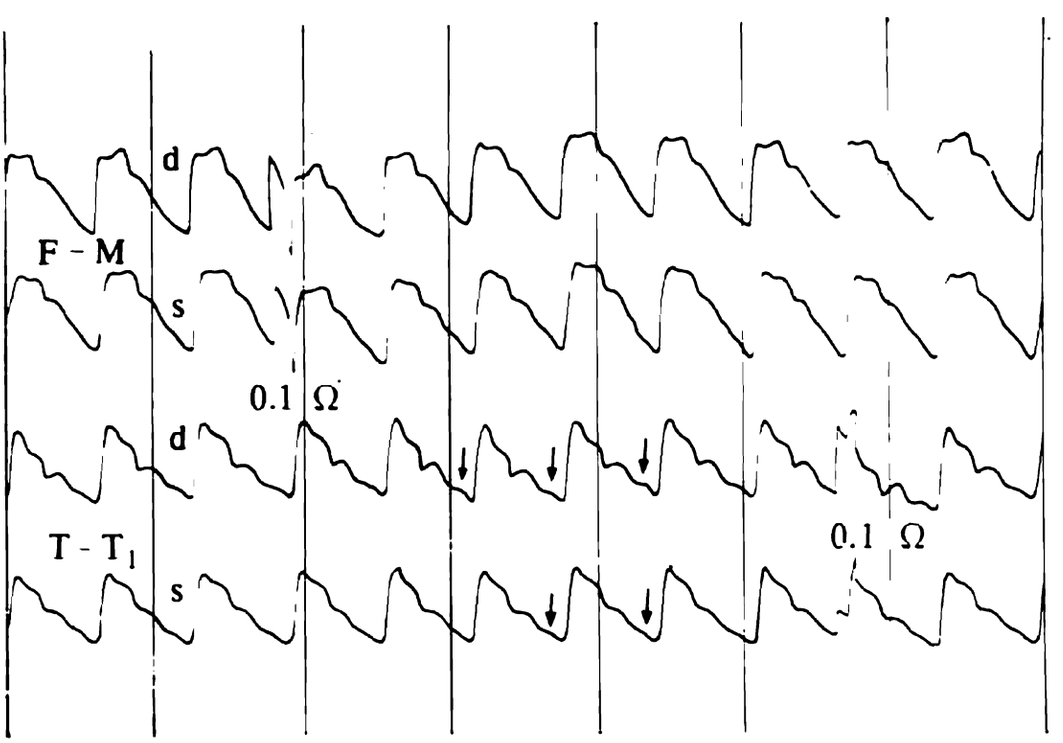


Fig. 17. REG of a female patient with vegetovascular dysfunction. There are signs of cerebrovascular dystonia and extracranial venous hypotension.

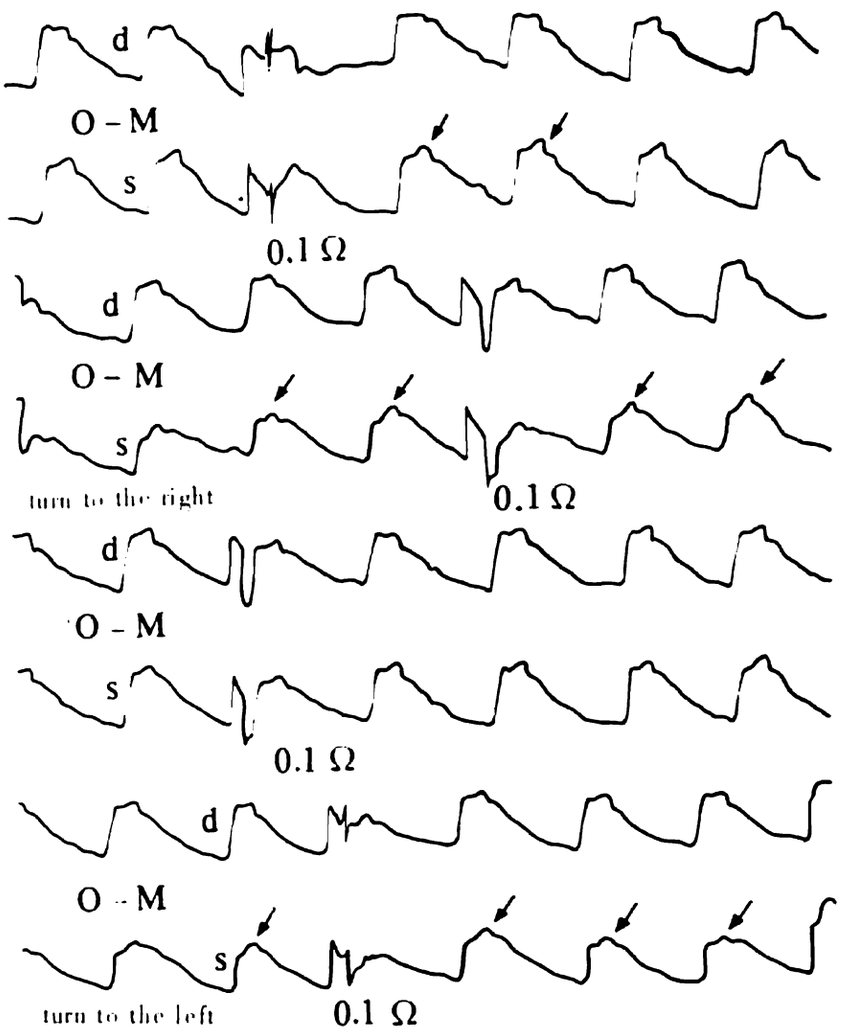


Fig. 18. REG of a female patient with vegetovascular dysfunction. There are signs of angiodystonia; angiospasm is observed in the left vertebral artery when the head is turned to either side.
O-M—occipital lead (vertebrobasilar areas); ↙—angiospasm

the vessels of the vertebrobasilar area in response to vertebrogenic stimulation of the vertebral arteries. Vascular response elicited by vasodilatators changes, but the pattern of the pulse waves is not fully normalized. Blood volume in various vascular zones of the brain is decreased as a rule, interhemispheric or regional asymmetry with respect to blood volume may be observed.

When manifestations of insufficiency of brain supply are most pronounced, the signs of gross organic changes in the vessel walls prevail (the waves are distinctly flat, their shape is often arch-like or pyramidal, the dicrotic peak is quite smoothed out, the time of the ascending part of the pulse wave becomes considerably longer). Vascular reactivity is decreased. There is a pronounced interhemispheric or regional asymmetry of blood volume, along with considerable decrease in cerebral pulse blood volume. Vertebrogenic effect on the vertebral arteries is most often of compressive nature. This

is not infrequently concomitant with signs of atherosclerotic stenosing of the vertebral artery (regional asymmetry of pulse blood volume combined with flattened pulse waves and their still greater flattening with a drop in their amplitude when the head is turned contralaterally).

Reactivity of cerebral vessels is studied also by means of the anti-orthostatic test on a tilt-table. The head of the patient is lowered 15 to 20 degrees, and he stays in this position from one to five minutes. It is assumed that the anti-orthostatic test, attended with redistribution of blood, provides specific conditions for better assessment of reactivity and adaptation capacity of the brain vessels.

The vascular response to the anti-orthostatic test is qualitatively different in healthy persons depending on their age. The reaction in young persons is seen on REG as a change of the vascular tonus (it is most often enhanced) without any rise in pulse blood volume. Older persons more often show changes in pulse blood volume (which is most commonly increased) indicating insufficient reactive increase in the tonus of the brain vessels.

REG does not reveal any change in patients with early manifestations of insufficiency of brain supply. However, many patients start complaining of dizziness and headache already after one or two minutes on the tilt-table. The patients with dyscirculatory encephalopathy show signs of the decrease of vascular tonus in the anti-orthostatic test which may indicate a decrease in reactivity of the vascular system.

Electroencephalographic studies reveal insignificant general changes in cerebral activity, diffuse changes in biopotentials, indicating dysfunction of the reticular and brain-stem formations; disturbances in cortex-subcortex interaction; a decrease in functional lability of cortical neurons as well as local changes in biopotentials related to the area with impaired circulation.

Biochemical studies reveal a rise in cholesterol, beta-lipoproteins, a drop in free fatty acids, an increase in fibrinogen content and in blood fibrinolytic activity.

In many patients aggravation of the vascular disease coincides with their critical days or periods of negative biorhythms by all cycles.

The *diagnosis* of insufficiency of cerebral circulation is based on the study of the whole vascular system (X-ray study of the aorta and major vessels, ECG, rheovasography, ophthalmoscopy, biomicroscopic study of the conjunctival vessels, biochemical studies of lipid and other kinds of metabolism), and on the study of the cerebrovascular system (rheoencephalography, ultrasound flowmetry). *Differential diagnosis* is made to exclude a possibility of a disease of the internal organs or brain pathology of other origin.

2.4. Treatment and Prophylaxis

The use of up-to-date diagnostic methods, including contrast study of the major vessels of the head and cerebral vessels, study of haemodynamics, metabolism, and brain function, enabled one to comprehend the diversity of the clinical signs of the disease and the influence of different factors on its course, and to assess the effect of therapeutic methods applied. All that gave grounds to develop new approaches to the treatment of insufficiency of cerebral circulation, among which the principle of differentiated treatment holds a special place. The methods for surgical treatment of cerebrovascular pathology have been developed in the past years owing to the advances in cardiovascular surgery.

All therapeutic measures in insufficiency of cerebral circulation are aimed at improvement of blood supply to the brain. It should be emphasized nevertheless that there must be strict differentiation and development of criteria in carrying out the treatment with due regard to features of the course and severity of the cerebrovascular disturbances, the degree of the manifestation and extent of the cardiovascular disease, the functional state of the brain, and the system of blood circulation as a whole, and the presence of concomitant diseases.

The difficulty of the problem posed by insufficiency of cerebral circulation lies in the fact that the disease often develops in relatively young persons and may take a latent course for a long time. Even patients with clinical signs of a cerebrovascular disease may not consult the doctor, and may be detected only in the course of some purposeful mass screening. The disease has remissions, often takes a progressive course and has various clinical manifestations.

The *treatment* of the disease can be successful only when it is *multi-purpose* and includes general measures and prescription of cardiovascular preparations. It is important to regulate periods of work and rest, rationalize nutrition, relieve psychoemotional tension, in some cases change occupation or the place of residence, apply treatment in a sanatorium and use remedial exercises. There are prerequisites for the success of drug therapy, which is not to be resorted to in every case, especially so for patients with early signs of insufficiency of cerebral circulation.

Sedatives and tranquillizers are indicated frequently. It is often quite enough for out-patients, especially with early manifestations of insufficiency of cerebral circulation.

Vasoactive drugs should be prescribed only when general measures do not yield noticeable results. In this case treatment is aimed mainly at the improvement of blood supply to the brain (Vincapan

[Vincaton], cinnarizine [Stugeron], Instenon, Desclydium, Trental) and metabolism of brain tissue (Gammalon [Aminalon], Ceremon, Cerebrolysin, Apoplectal [Alpha-apoplectal], Lipobolite), normalization of the function of the heart, other internal organs, endocrine glands, and general haemodynamics.

The patients often have pronounced cardiovascular diseases: hypertensive disease, atherosclerosis, diabetes mellitus, coronary insufficiency, etc. All that requires additional precaution in the choice of drugs, and use of additional combinations. Treatment has to be adaptable and it needs some rational medical tactics. Maximal effect (complete many years' remission) is quite possible for the patients with early signs of insufficiency of cerebral circulation.

In *vegetovascular dysfunction* the following measures are recommended: (1) daily regular physical exercises (gymnastics), available hydrotherapy (shower), and walks; rational use of week-ends, holidays, and leaves; (2) regulation of meal times, quantity and quality of food, an adequate amount of vitamins. Rational diet should be prescribed to all patients suffering from diabetes, hyperlipaemia, hypercholesterolaemia, obesity, diseases of the gastrointestinal tract, liver, kidneys, or to those having disposition to arterial hypertension.

When there is retention of stools, such laxatives as buckthorn extract, buckthorn bark or rhubarb are prescribed, and sometimes more effective purgatives: magnesium sulphate, phenolphthalein, Agarol, Microlax, Neunzehn, Normacol and Regulax. Timely gastric evacuation unloads the organism, improves renal function, decreases blood congestion in the intestinal veins and promotes better general blood circulation. Physical exercises are very useful, particularly those for prelum abdominale. Abdominal muscles grow stronger, and intestinal peristalsis improves.

Sleep should take no less than eight hours every night, and there should be a rest during the day, if possible, for 30-40 minutes. In insomnia valerian preparations are prescribed; Valocordin; Laevomepromazine maleate (Nozinan, Minozinan, Tisercin) in a dose of 10 to 25 mg; Eunoctin (often in combination with valerian tea or 30-40 drops of Valocordin taken before sleep). In case these have no effect, it is advisable to prescribe for a short period such soporifics as vinylbital (Speda, Optanox), Tardyl, potassium nitrazepate (Nitrazepam, Mogadon), glutethimide (Noxiron), cyclobarbital (Phanodorm), Rogypnol, and others, combining them periodically with small doses of tranquillizers.

The patients should avoid neuropsychic overstrain, exposure to the sun, hot bath, mountain-climbing (especially over 1000 m above the sea level), alcohol, tobacco, strong tea or coffee, sexual overindulgence.

The complex of aetiological and general measures should be com-

bined with pathogenic therapy. Preparations regulating the central nervous system are prescribed.

Ipronal (Vasalgin) is given in headaches of vascular origin (1 tablet 3 times a day for 4 or 5 weeks, the course to be repeated after 2 or 3 weeks). A therapeutic effect is seen no sooner than 1 or 2 weeks after the beginning of the course. *Methyldiazepinone (Diazepam, Valium, Seduxen)* is indicated for treating neurosis and vegetovascular dysfunction (2.5 to 5 mg per os 3 times a day or 2 ml intramuscularly before sleep). *Valosedan* is given for treating neurasthenia and vegetative dysfunction (1 teaspoonful 2 or 3 times a day). *Dimethylergometrine (Methysergide, Deseryl) retard* is a highly active serotonin antagonist. Indications: acute form of relapsing migraine, headaches of vascular origin. Dosage: $^1/_2$ or $^1/_4$ of a tablet for the first day, then the dose is gradually increased up to 1 or 2 tablets a day. Course: 3 to 6 months. *Chlordiazepoxide (Librium)* produces a sedative effect on the central nervous system (0.005 to 0.01 g 2 or 3 or 4 times a day). *Meclofenoxate (Lucidryl, Acephen)* stimulates the central nervous system. Indications: asthenic states, cerebrovascular diseases, hypothalamic disorders. Dosage: 0.1-0.3 g 3-5 times a day; hypodermic, intramuscular or intravenous injections 0.25 g each. Course: 1 to 3 months. *Thioridazine (Melleril, Sonapax)* is indicated for neurogenic gastro-intestinal or cardiovascular disorders and sleep disturbances (0.005-0.01 g 2 or 3 times a day and 0.005 g before sleep). *Meprobamate* (metrothan) is prescribed for treating vegetative dysfunction and sleep disturbances (0.2-0.4 g 2 or 3 times a day; for insomnia 0.2 or 0.4 or 0.6 g before sleep). *Dimetotiazine (Migristene)* has an antiserotonin, antihistaminic, antianaphylactic, antiemetic, and analgetic effect. Indications: migraines, headaches of various aetiology. Dosage: 0.02 g 2 or 3 times a day. *Amitriptyline with perphenazine (Mutabon)* provides a sedative effect (1 tablet 3 or 4 times a day). *Methylpentynal (Oblivon)* is a preparation made of plants; it is used as a sedative for insomnia and vegetovascular dysfunction. Dosage: a teaspoonful every 4 hours, 2 teaspoonfuls before sleep. *Tazepam* in its pharmacologic effect is close to that of Librium or Seduxen. Dosage: 10 mg 1 to 4 times a day. *Clemastine fumarate (Tavegil)* is an antihistaminic preparation. Dosage: a tablet per os or an ampule intramuscularly (or intravenously) in the morning and at night.

Carbamazepine (Tegretol, Finlepsin) is indicated for treating vegetative paroxysms (0.2 g 2 or 3 times a day). *Alimemazine (methylpromazine, Teralen)* is a mild neuroleptic preparation with a wide range of effect. Indication: vegetative dysfunction. Dosage: 2 to 8 tablets a day. *Laevomepromazine maleate (Tisercin)* has a pronounced sedative effect; starting from 0.025 g, the dose is gradually increased up to 0.1 or 0.15 g; the course of treatment should last 1 to 3 months. *Perphenazine (Trilafon, Etaperazine)* is a neurolep-

tic with a wide range of effect (0.002, 0.004, 0.008 g 3 or 4 times a day after meals).

Soviet-made Pirroxan, an adrenoblocker, is very efficacious for sympathoadrenal paroxysms of hypothalamic origin. 1 ml of it is prescribed to be injected intramuscularly for 14 days in the morning and at night. If necessary, another course is prescribed. To prevent paroxysms, 0.015 g of the drug is given per os 1 to 3 times daily.

Another preparation, Butiroxan, is used for treating patients with vagoinsular hypothalamic paroxysms in a dose of 0.015 g. It improves general condition of patients, increases arterial pressure, improves cardiac activity, and makes breathing satisfactory. Course: 4 weeks. The preparation taken 1 or 2 times a week prevents relapses of the attacks.

Soviet-made preparation Patrinozid 'D', isolated from *Patrinia medium* (the family of Valeriana), is efficacious for treating vegetative dysfunction with a tendency to arterial hypertension and cerebrovascular paroxysms. The preparation is given per os in a dose of 0.05 g 3 times a day after meals for 20-25 days, then after an interval of 10-14 days a course for 'fixation' is advisable with the same dosage for 10 to 14 days. Patrinozid 'D' decreases heightened excitability, emotional lability, normalizes sleep, prevents cerebral paroxysms, stabilizes arterial pressure. The therapeutic effect of the preparation usually appears in 4 or 5 days. A single dose of 2 tablets brings about a mild sedative effect. Belloid, Bellaspon (Bellataminal), Bellergal, thiethylperazine (Torecan), hydroxyzine (Atarax), Lorazepam (Ativan), Opipramol (Incidon), chlordiazepoxide with clidinium bromide (Librax) are also indicated.

The treatment of insufficiency of cerebral circulation has to be carried out jointly with measures on primary and secondary prophylaxis of hypertension. These are regulation of work and rest, sleep for 9 to 10 hours a day (minimum 8 hours at night), elimination of causes for neuropsychic overstrain, reduced consumption of salt. Such general measures may become therapeutic during the early stages of hypertensive disease, and they are a necessary background for drug therapy in the later stages of the disease. Both tactics of treatment and choice of drugs depend on the stage of the disease and establishment of its leading pathogenic mechanisms.

Sedatives and general measures suffice during the prehypertensive stage of the disease. In addition to this an individually selected dose of reserpine (Serpasil) is prescribed during the first stage* of hypertensive disease. Propranolol (Inderal) is indicated for patients with

* According to A. L. Myasnikov's classification, accepted in the USSR, there are the following stages of hypertensive disease: IA—prehypertensive, including hyper-reactivity; IB—transient, reversible; IIA—unstable; IIB—stable; IIIA—compensated, without sufficient visceral disorders; IIIB—decompensated stage.

the hyperdynamic syndrome (predominant rise in systolic arterial pressure and tachycardia). Dihydrochlorthiazide (hypothiazide, Esidrex) or Gigroton (20 to 50 mg 1 or 2 times a week) is prescribed to patients with 'loose' habitus, particularly in elevation of their diastolic pressure.

Treatment in the second stage of hypertensive disease should be combined and constant using maintenance doses. Combination of reserpine with hypothiazide prescribed periodically is often quite sufficient. It is possible also to give hexamethonium bromide (Depressin) or Adelphan, Clonidine with Chlortalidone (Combipresan), hydralazine (Apresoline), closudimeprymil (Clopamide, Brinaldix), Brinerdin, Gygroton-50. Dimecarbin combined with hypothiazide is prescribed in case of poor tolerance to reserpine (Serpasil). Considering the leading pathogenic syndrome, either clonidine (Catapressan, Haemiton) is prescribed (influencing central mechanisms mainly) or antiadrenergic drugs, such as guanethidine (Octadine, Isobarin), guanethidine sulphate (Ismelin), methyl-dopa (alpha methyl dopa), influencing peripheral pressor mechanisms.

In persistent hypertensive disease (stages IIB or III) administration of only one drug is less effective. The usual combinations are: reserpine (Serpasil) and hypothiazide, Dimecarbin and hypothiazide, Adelphan-esidrex 'K' or Rautrox. Alpha methyl dopa is added when there is no desirable effect. In case a combination of three drugs does not help, Ismelin or Isobarin is to be prescribed. When the use of four drugs is still ineffective, it is recommended either to apply Catapressan (Haemiton) or to switch over to propranolol (Inderal) which blocks beta-adrenergic receptors. Inderal medication may be combined with hypothiazide. Further on, arterial pressure is maintained at an optimal level by means of minimal maintenance doses. The rule of gradual decrease of arterial pressure should be observed.

When there is stage III of hypertensive disease, it is not in every patient that arterial pressure could be normalized. In any case there should be constant check-up of regional blood circulation (ECG for the heart, REG for the brain). Symptomatic and pathogenic treatment in syndromes related to other organs (heart, brain, kidneys) should be carried out.

A basic approach to hypertensive disease is continuity of in-patient and out-patient treatment, careful choice of maintenance doses, and regular dispensary follow up.

Atherosclerosis patients undergo differentiated treatment with the aid of diet and drugs.

A diet is prescribed considering the nature of the change in lipid metabolism. In hypercholesterolaemia fats of animal origin should be reduced, while the amounts of carbohydrates and especially of protein are to be kept within standard limits or slightly reduced. Egg yolk, brain, caviar, liver are to be limited or excluded. One

third of fats is to be of plant origin. Patients having hypertriglyceridaemia are to be limited with easily assimilated carbohydrates (no more than 250 g a day), which are the main source of triglyceride synthesis. The amount of proteins and fats in the diet should be kept within normal limits. In mixed type the diet should be compiled taking into account two above-mentioned variants. In case a rational diet does not correct lipid metabolism or does it insufficiently, drug therapy should be carried out.

In hypercholesterolaemia preparations containing sterols of plant origin and saponins are indicated: linaethol (20 ml once a day before or during meals), Arachiden (10 to 20 drops 2 times a day), vitamin F-99 (a capsule 2 or 3 times a day), beta-sitosterol, Diosponin (100 mg 2 or 3 times a day), Colestyramine (Cholestyramine). The preparations are taken for 3-4 weeks. The course is repeated after an interval of 1-2 months. In increase of triglycerides heparin or heparinoids are more effective, as well as pancreatin and lipocain. Atheroid is prescribed in a dose of 4 to 6 tablets a day before meals. Atromid (Clofibrate with androsterone) and its analogues (Clofibrate, Atromidin, Miscleron, Regelan) are more effective in patients with the mixed type of disturbances of lipid metabolism. Nicotinic acid is also used (up to 1.0 g a day for 3-4 weeks, repeatedly), Vasolastin (2 ml, intramuscular daily injections for 2 weeks, then 3 times a week for 3 months, then 2 times a week for 6 months), Tioctan (one tablet 3 times a day).

Elimination of *risk factors* is the most realistic point in the *prophylaxis* of insufficiency of brain circulation at the present level of knowledge. The risk factors of primary prophylaxis concern are obesity, hereditary predisposition, stress, hypodynamia, smoking, heavy drinking, meteosensitivity. *Secondary prophylaxis* is to be focused on preventing aggravations of the disease, transient disturbances of brain circulation, and strokes.

Multiform prophylactic measures carried out among the high-risk population groups, which are actively screened, are the most advisable method of *primary prophylaxis* today. It has to be started in the age when there is still hope to suppress the development of insufficiency of cerebral circulation, i.e. at 40-49 years and even among younger individuals using for this purpose proper diet, drug preparations, physical exercise, and control of harmful habits.

In addition to measures of primary prophylaxis attention has also to be drawn to *secondary prophylaxis* of insufficiency of brain circulation in order to prevent aggravations and possible complications of the disease already developed.

Constant *dispensary observation* should be provided. The main principles of *dispensary care* in cerebrovascular diseases imply: (1) detection of the contingent of patients and their filing; (2) study of occupational and living conditions and job placement; (3) diag-

nosis with due regard to aetiology, pathogenesis, risk factors, and the stage of insufficiency of brain circulation; (4) elaboration of a plan of prophylactic and therapeutic measures; (5) medicinal treatment, physiotherapy, oxygen therapy, massage, remedial exercises, logopaedic exercises, psychotherapy; (6) examination and prophylactic treatment in hospital; (7) spa and sanatorium treatment, and treatment in sanatorium departments attached to hospitals; (8) health education of the population; (9) assessment of the efficacy of the therapeutic and prophylactic measures.

Efficacious measures for reducing the importance of risk factors of insufficiency of brain circulation do not fully solve the problems of both primary and secondary prophylaxis. It is also necessary to provide complex sociohygienic measures, health education of the population, adjustment of the health-care system to the tasks of active early detection of patients with insufficiency of brain circulation and healthy persons with high risk factors, as well as to provide the dispensary care for larger contingents of the population.

Chapter 3. Transient Disorders of Cerebral Circulation (Cerebrovascular Crises)

3.1. Introduction

The concept of 'transient disorders of cerebral circulation' covers various dyscirculatory phenomena in the brain, characterized by short-term and paroxysmal disturbances of cerebral haemodynamics and unstable variously pronounced general or focal symptoms. In compliance with the WHO recommendation, transient disorders of cerebral circulation embrace the cases in which all focal symptoms disappear in no more than 24 hours: if they last longer, they are considered to be cerebral strokes.

Acute onset of such transient disorders of cerebral circulation has been described elsewhere as cerebrovascular angiospasm, dynamic disturbance of cerebral circulation, transitory ischaemic attack, acute brain oedema, acute hypertensive encephalopathy, prestroke state, 'prethrombosis', ischaemic encephalopathy, microstroke. However, none of the above-mentioned terms reflects the essence of the syndrome, or accounts for the revelant processes occurring in vessels and brain tissue.

The dyschaemic syndromes, though described in different terms, are quite identical. Variegation of their clinical signs stems from various pathogenic mechanisms and various duration, extent and localization of the dyscirculatory phenomena. The term 'transient disorders of cerebral circulation', apart from transient cerebral ischaemia, covers hypertensive crises, regardless of whether or not both of them show in general or focal cerebral symptoms.

Transient disorders of cerebral circulation (TDCC) are among the most common forms of disturbances of cerebral circulation. The TDCC incidence among neurological in-patients is within the range of 13-21.4 per cent of those with acute disturbances of cerebral circulation. But the TDCC incidence rate is still greater among out-patients: 56.7 per cent of total cases of acute disturbances of cerebral circulation, inasmuch as such patients are commonly not hospitalized. Sometimes TDCC may be slightly pronounced, and therefore patients do not apply for medical help.

3.2. Aetiology

Transient disorders of cerebral circulation are observed in many diseases, the most important of which are those affecting cerebral vessels and the major arteries of the head, mostly hypertensive disease, atherosclerosis, and their combination. TDCC is less common in cerebral vasculitis of various aetiology (infectious, infection allergic, rheumatic, syphilitic, etc.), in systemic vascular diseases (obliterating thromboangiitis, arteritis in lupus erythematosus, periarteritis nodosa), in aneurysms and angiomas, blood diseases (anaemia, polycythaemia), myocardial infarction and other heart diseases (Morgagni-Adams-Stokes syndrome, cardiac fibrillation, paroxysmal tachycardia, valvular heart diseases, etc.), coarctation of the aorta, atherosclerosis of the aortic arch, acrotism, disorder of venous circulation. The pathology of the major vessels of the head is important as well (stenosis, thrombosis, abnormal tortuosity, kinks, hypoplasia, developmental anomaly). A lesion in the cervical spine (osteochondrosis) may also affect cerebral blood flow by pressure and consequent spasm of the vertebral arteries. Transient neurological symptoms of vascular origin may be encountered in cerebral tumour (both initial and metastatic), cysticercosis, infections and intoxications (uraemia, etc.), phaeochromocytoma. Cerebrovascular crises occur in hypotonic states and vegetovascular dysfunctions.

Thus, TDCC may be observed in many diseases. Therefore even when the symptoms are mild, there is a need in a thorough examination of the patient for establishing diagnosis of the principal disease.

3.3. Pathogenesis

Cerebrovascular spasm can be one of the mechanisms triggering TDCC. When a contrast substance is introduced into the carotid, there is a spasm in its branches supplying the brain, which is seen in the angiograms. There is angiospasm of the fundus oculi in hypertensive crisis; a thrombus or embolus irritating the wall of a major vessel causes a spasmodic reflex in distal arteries; stimulation of a sympathetic neuroplexus brings about spasms in the pial arteries; operations performed on the vessels of the circle of Willis sometimes cause a spasm in the branches of the middle cerebral artery.

Angiospasm may initiate a chain of pathological phenomena. Depending on the degree of the spasm, blood flow in the affected vessel decreases or even stops thus causing anaemia and hypoxia and damage to cerebral tissue and the vessel wall. The permeability

of the vessel wall increases, erythrocytes escape and there is transudation of plasma into the surrounding brain tissue.

Cerebrovascular spasm is triggered by stimulating the neural apparatus of the vessel walls. Important are both mechanical influences, such as sharp push of the pulse waves in hypertensive crisis, and changes in physicochemical and biochemical blood properties (elevated content of adrenergic substances). Parietal thrombi and emboli which do not occlude the vascular lumen completely, may cause a reflex angiospasm. Emboli are usually tiny particles separated from thrombi. They may be found within the heart cavity and in major vessels. It is supposed that they may be cholesterol crystals rejected from decomposing atheromatous plaques.

Many scientists, however, do not admit that cerebral angiospasms may trigger TDCC. Some of the authors doubt the role of spasm of cerebral vessels taking into consideration their low capacity for constriction and the presence of the sinocarotid apparatus which is a powerful regulator of blood pressure.

Apart from cerebrovascular spasms, the triggering effect may be caused by the *failure of autoregulation of cerebral blood flow* in a sharp rise or drop in arterial pressure or by vascular *stasis*. Some writers consider the role of *cerebrovascular insufficiency* in the pathogenesis of TDCC. The concept of cerebrovascular insufficiency denotes circulatory insufficiency in some area of the brain which may show in repeated attacks of focal loss of the brain functions. Usually the attacks have no consequences but may also turn out to be prodromes of a coming stroke. They are either monotypic or have different symptoms, and commonly result from circulation disturbances within the area of one and the same vessel. The attacks are caused by local ischaemization of the neural tissue around vessels narrowed with atherosclerosis, more often when there is a decrease in general arterial pressure due to haemorrhages from the internal organs, hypersensitivity of the carotid sinus, the rush of blood to the surface vessels after a hot bath, etc. It is especially unfavourable, when a drop in arterial pressure is matched with a hypoxic state (pneumonia, pulmonary oedema, anaemia).

Among various extracerebral factors contributing to the development of TDCC, prevailing is the pathology of the extracranial parts of the major head vessels such as partial or complete occlusion and abnormal tortuosity of the carotid and vertebral arteries. Atherosclerotic changes in the carotid and vertebral arteries are found in 40 per cent of the cases.

The common carotid artery may have stenosis and thrombosis at its bifurcation into internal and external carotids. Apart from stenosis of the vessel and disturbances in cerebral blood flow negative reflex influences on cerebral circulation may arise from the carotid sinus. Occlusion of the extracranial part of the internal carotid ar-

tery causes occurrence of small foci with transient neurological symptoms in maintenance of collateral circulation. Simultaneous occlusion of the internal carotid and stenosis of the vertebral artery do not always lead to severe cerebral lesions.

When collateral circulation is well developed, the brain is supplied with blood so abundantly that only mildly pronounced, soon disappearing symptoms may occur. The adaptative role of collateral circulation is essential and is provided by four levels of collateral blood flow: extracranial flow, that in the base of the brain, on its surface and inside the brain.

Diseases of the organism's other organs and systems are important in TDCC development, particularly the condition of coronary circulation, and combined disturbances of cerebral and cardiac haemodynamics which constitute the coronary-cerebral syndrome.

Transient hyperaemia (arterial dilatation and early filling of brain surface veins as a response to brain ischaemization) is also important in the TDCC pathogenesis. The blood flow rate slows down, and the blood turns to be hyperoxygenated.

The TDCC clinical signs may depend not necessarily on a lesion in the relevant vessel, but on some inadequate haemodynamic shift of a compensatory character (the steal syndrome). Therefore sometimes the symptoms are found to be related to the area of an intact vessel.

Abundant anastomotic connections provide sufficient possibilities to make up for circulation insufficiency when there is occlusion of some of the brain supplying vessels. But under certain conditions collateral circulation is inadequate physiologically. Such a peculiar disorder of cerebral circulation appears after occlusion of the proximal sections of branches of the aortic arch (i.e. of the subclavian, innominate, and common carotid arteries); it has been named the *phenomenon of stealing.*

There are different forms of the steal syndrome. Thus, in the subclavical variety of the steal syndrome, which is due to occlusion of the initial portion of the subclavian artery, the vertebral artery on the side of occlusion becomes a collateral for the arm, where the blood flow is reversed from the vertebrobasilar system into the arm arteries, impairing cerebral supply. When the arm is much exercised, blood flow into the brain decreases (stealing), thus causing dysfunction of the brain-stem.

Because the branches of the aortic arch are frequently affected, one should take into account possible negative effect on cerebral haemodynamics of reversed blood flow in collateral circulation on the extracranial level.

The *phenomenon of stealing* also occurs when other vessels are occluded, e.g. 'the siphon effect' with reversed blood flow from the internal carotid into external one when the common carotid is oc-

cluded; when the ostium of the external carotid on the contralateral side is occluded, the blood flows into it from the vertebral artery through the anastomoses of its muscular branches with the occipital artery or from the internal carotid through its anastomoses with the ophthalmic artery. This may lead to both brain-stem and hemispheric dysfunction, since part of the blood flows to the face and extracranial tissues instead of the brain.

Transient disturbances of cerebral circulation may be caused by *microthrombosis* in polycythaemia, macroglobulinaemia, and thrombocytosis. Microthrombosis may be caused by *microemboli* breaking off from fibrinothrombocytic parietal thrombi or from disintegrating atherosclerotic plaques in the ascending part of the aorta or the major vessels of the head; they may also break off due to valvular heart disease, arrhythmia, myocardial infarction. The thrombi, which are the source of such emboli, may form in the carotid due to a trauma by the transverse processes of the first cervical vertebra or in the vertebral artery due to a trauma in the junction of the first two cervical vertebrae when there are anomalies (spondylosis or the Klippel-Feil syndrome).

An embolus may completely disintegrate or resolve. In the meanwhile, micronecrosis with perivascular oedema may develop; when such an oedema disappears and the relevant collateral circulation improves, the clinical signs disappear as well.

Due regard has to be paid to *physicochemical* blood changes (elevated viscosity, aggregation of formed elements, anaemia) and *biochemical* changes (in diabetic ketosis and hyperglycaemia, lipaemia, changes in the coagulation and anticoagulation systems, respiratory function, and metabolism). Thus, in a number of cases of insufficiency in the vertebrobasilar or carotid arterial system, a relation is found between ischaemic cerebral phenomena and rich food. On the other hand, symptoms of circulatory insufficiency made up for by insulin were found in diabetic ketosis and hyperglycaemia. It was shown that introduction of high-molecular mass substances, in particular food fats, causes changes in blood physical properties, such as a rise in viscosity, occurrence of 'coin stacks' of erythrocytes, and increased ESR. Experiments revealed that introduction of rich food into animals' stomachs promotes erythrocyte accumulation in small pial vessels and leads to a decrease in blood flow rate owing to changes both in the structure and colloid concentration of plasma.

Metabolic disturbances of the brain may bring about a failure in cerebral blood flow autoregulation, i.e. in the property of the brain to maintain its blood flow at a certain level, despite variations of arterial pressure, and blood gas and metabolic content (pCO_2, pO_2, pH). The property is known as metabolic vasomotor control.

Both general and regional cerebral blood flow is influenced also with *elevation of pressure of cerebrospinal fluid.*

Various *nervous reflex mechanisms* contribute to the origin of TDCC and their clinical picture. Among the special vascular reflexogenic zones especially important is the sinocarotid zone — a 'forward position' on the way of the cerebral blood flow. Many disturbances of cerebral circulation (transient, stable, etc.) are caused by abnormal sinocarotid reflexes. There are important reflexogenic zones in the vessels of the circle of Willis, in the anterior and middle cerebral arteries, and in the intracerebral arteries.

Functional disturbances of the reflexogenic zone may be caused by various structural changes in the vessel walls (atheromatosis, hyalinosis). Disturbances of cortical neurodynamics and of the limbic, hypothalamic, reticular, and brain-stem formations and sympathetico-adrenal dysfunction are also important. Dysfunction of the sympathetic and parasympathetic parts of the vegetative (autonomic) nervous system and related neurohumoral disorders, as well as impairment of adrenergic and cholinergic effects bring about pathological response from cerebral vessels.

Changes in nerve cells caused by the dyscirculatory phenomena in the brain originate primarily from hypoxia. The changes in nerve cells may either have various degree of reversibility or become deep, organic depending on the duration of circulatory dysfunction. Concomitant oxygen hunger of the vessel walls entails their higher permeability for the blood plasma, insinuation of plasma through the vascular walls (plasmorrhagia), which may cause perivascular oedema, and in some cases erythrodiapedesis. Therefore it cannot be denied that transient disturbances of cerebral function may sometimes be caused by *microfocal haemorrhages* as well.

There are data on the *immunochemical* changes in patients with disturbances of cerebral circulation. Specific antibodies have been discovered, directed against cerebral tissues and antigens of the vessel walls. Some cases of cerebral circulation disorder are supposedly due to the antibodies fixing on the vessel walls, since that may trigger pathological mechanisms, causing higher vessel permeability and stimulating the process of thrombus formation.

In vascular lesions of the nervous system, different in the aetiology, patients with TDCC develop *cerebral microcirculation disturbances*, disorders of nutrition of cerebral matter and of biochemical and oxidation processes, all of them various in their pathogenesis and degree of manifestation.

Thus, different mechanisms may trigger TDCC. The transient character of disturbances of cerebral circulation is stipulated by the restoration of cerebral blood flow. The reversible process of the protective inhibition as a response of the nerve cells to hypoxia is also important.

Pathomorphological studies reveal disintegrating atherosclerotic plaques in the aortic arch, in the carotid, vertebral, and basilar arteries, emboli in minor cerebral vessels with microcirculation disorders, destruction of the vessel walls and dyscirculatory plasmorrhagia, stasis, and perivascular oedema. Intramural haemorrhages are seen in the vessels, stratification and necrobiosis of the walls, formation of aneurysms, and sometimes of parietal thrombi. Minor ischaemic necroses and erythrodiapedetic haemorrhages occur in the surrounding cerebral tissues. The morbid changes prevail in the vessels and around them, doing little damage to the cerebral parenchyma.

3.4. Clinical Picture

The onset of TDCC is more often abrupt due to the rapid breakdown of vasomotor functional regulation (changes in blood flow) and biochemical equilibrium in the organism (metabolic disorders). It is less often marked with gradual, slow development of cerebral symptoms: first there is heaviness in the head, mild transient dizziness, then an acute headache, state of fainting with disturbances in orientation, and vomiting. The study of the case histories shows that the crisis has often been prepared long before. It is preceded by excessive nervous and psychic strain or a psychic trauma. Failure in vasomotor regulation occurs after overwork, insufficient sleep, irregularity in the sequence of work and rest, excitation. Sometimes a breakdown is promoted by harmful factors (infection or intoxication). Individual features of the patient, such as vasomotor instability and hyper-reactivity of the vascular system, play their part as well, providing the background for development of abnormal vascular reactions.

The clinical signs of TDCC differ depending on the degree of severity, duration, and pathogenic peculiarities of disturbances of cerebral circulation, the nature and stage of the principal disease, as well as on the predominant localization of the dyscirculatory phenomena.

Analysis of symptoms allows general TDCC to be distinguished, when there are only general cerebral symptoms, as well as *regional* ones with localization in a certain vascular area (the *dyscirculatory carotid* and *dyscirculatory vertebrobasilar syndromes*), and *combined* TDCC with a primary or secondary disorder of cerebral circulation, when it follows the development of crises in other organs.

The difference in severity and duration allows *mild*, *medium*, and *severe* transient disorders of cerebral circulation to be distinguished.

TDCC with *general cerebral symptoms* only are marked by headache or sensation of heaviness in the head, dizziness, nausea, vo-

miting, emotional instability, weakness, concomitant vasomotor phenomena on the skin of the neck and breast, excessive sweating, sensation of lack of air, palpitation, possible short-time disorders of consciousness. The patients complain of confusion, say that 'everything is floating' before their eyes or 'everything's got dark'. More advanced TDCC are marked by acute headache and dizziness, a 'veil' before the eyes, nausea, vomiting, noise in the head, weakness. The skin of the face is pale, cool, and humid. Epileptic fits may occur in some cases.

When there is predominance of *dyscirculatory phenomena in the system of the internal carotid*, most common are the symptoms, indicating pathology of the cortical areas of the brain. Disorders of sensation are often observed, such as numbness, sometimes with pricking, over a limited area, covering the skin areas of the face, limbs, some fingers. The numbness sometimes occurs simultaneously in a half of the upper lip, half of the tongue, in the inner part of a forearm and hand, in the fourth and fifth fingers. An examination shows hypaesthesia, deficiency of orientation and discrimination. Cases with hemitype disorder of sensation are less common. Impairment of sensation may come both with and without motor disorders — signs of paresis, somewhat more often limited ones, involving only an arm, a hand, individual fingers, and in some cases only a leg. Hemiplegic type is less common. There is usually a rise in the tendon reflexes and a decrease in the skin ones, and sometimes Babinski reflex is observed. Transient speech disorders in the form of aphasia often occur jointly with some sensational and motor disorders in the right side of the body. Some patients suffer from fits of Jacksonian epilepsy, and show the optico-pyramidal syndrome.

The *dyscirculatory vertebrobasilar syndrome* is marked by systemic dizziness and vegetovascular disorders. The usual complaints are: noise in the ears, sometimes headache (mostly occipital), rotation of the surroundings, in other cases — the 'veil' before the eyes, sensation of dislocation of one's own body, which is intensified when the head's position is changed. Vegetovascular reactions develop: nausea, vomiting, paleness, cold sweat. There may be nystagmus, instability in the Romberg test, failure in the coordination tests. All these symptoms are related to peripheral vestibular stimulation in the area of the internal ear, supplied by the branches of the basilar artery, in particular by the internal auditory artery.

Patients with transient disorders of circulation of the brain stem complain of nausea, heaviness and noise in the head, systemic dizziness, vomiting, and hiccup. Such disturbances include visual disorders such as photopsia, metamorphopsia, blurred seeing, defects in the fields of vision; impairment of hearing; diplopia, paresis of the ocular muscles and gaze, impairment of convergence;

facial tactile disorders (especially around the mouth in the Selder zones); dysarthria, dysphonia, dysphagia; pyramidal symptoms without pronounced paresis, alternating syndrome (seldom); insignificant disorders of sensation; disturbances of statics and coordination of movements and vestibular disorders accompanied with nystagmus. General weakness, adynamia, malaise, rapid exhaustion and abnormal fatigue are often encountered. There are paroxysmal rises in arterial pressure. The vegetative vascular syndrome manifests itself in attacks of general weakness with profuse perspiration, tachy- or bradycardia. Sudden drop attacks without loss of consciousness occur in patients with pathology of the cervical vertebrae when the head is turned or thrown back. The drop attacks are associated with transient loss of the postural tonus caused by ischaemia of the lower oliva and the reticular formation. The Untercharnscheidt syncopal vertebral syndrome is close in pathogenesis: attacks of loss of consciousness accompanied with muscular hypotonia. The paroxysms are preceded by headache of vertebrogenic nature, visual and auditory disorders. Attacks of lobe psychomotor epilepsy are possible. Memory is usually affected, especially that of current events, to the extent of severe, acutely progressive loss of memory. These changes appear to be associated with lesions in different structures of the limbic system and the mediobasal parts of the temporal lobes. There may be reflex attacks after stimulation of the sympathetic plexus of the vertebral artery. The syndromes of hypersomnia and cataplexy and vegetovascular crises are among other paroxysmal states which evolve due to hypothalamic and brain-stem disturbances of vascular origin.

There is often simultaneous atherosclerotic lesion in both the carotid and vertebral arteries, especially in middle-aged people. *Multiple* affection in the major head vessels may bring out symptoms of circulation disorders both in the carotid and vertebrobasilar areas in various *combinations*. Sometimes symptoms indicating affection of various areas appear simultaneously. The pathogenesis of the dyscirculatory phenomena, however, may be different. One should consider insufficiency of general haemodynamics, resulting in the decrease of the blood flow below the critical level in several most stenosed cranial vessels.

The mechanism of simultaneous occurrence of signs of affections of different vessels may be of quite another nature. In long-term insufficiency of one vascular system compensation can be provided by the other system, which begins to supply blood to a brain area usually not supplied by it. Thus, in case of occlusion or stenosis of the vertebral arteries, angiography of the carotid often shows the contrast substance in the posterior cerebral and basilar arteries, while in occlusion of the carotids the contrast substance introduced into the vertebral arteries fills the middle and anterior cerebral

arteries. Therefore in occlusion of the vertebral arteries, a decrease of blood flow in the carotid may cause dysfunction of the brain stem (systemic vertigo, static disorders, diplopia, photopsia), which may prevail in the clinical picture accompanied with mild dysfunction of hemispherical origin (aphasic disorders, cortical paresis, etc.). The explanation is that the basilar artery and its branches are mainly supplied by the carotid arteries, becoming therefore their end-branches. Hence a decrease of blood flow in the carotid system may mostly affect its new terminal region — the brain stem.

Combined transient disturbances of cerebral circulation are manifested mainly by a syndrome including symptoms of both cerebral disturbances and coronary pathology. Coronary symptoms more often appear first (acute anginal pains, other sensations in the cardiac region, ECG changes), and then cerebral symptoms. Neurological signs of this symptom complex vary from mild or medium cerebral disorders with general symptoms of brain dysfunction to pronounced focal pathology, frequently prevailing in the clinical picture, and sometimes even shadowing primary affection of the myocardium. Mild or medium cerebro-coronary crises are most common: they are first displayed by cardiac and retrosternal pains of the type of angina pectoris, face paleness followed by hyperaemia, perspiration, headache in the temporal region or sometimes in a half of the head, vertigo, clouding or short-term loss of consciousness, sometimes nausea, vomiting, noise in the ears and head. Severe cerebro-coronary crises are marked by more or less pronounced neurological disorders with loss of movements and sensory disturbances, which predominate so much in the clinical picture that an incorrect inference might be drawn of the primary cerebral pathology.

All these features of cerebro-coronary crisis are clearly seen in myocardial infarction or even in attacks of angina pectoris with focal coronary insufficiency of the ischaemic type, established by ECG. In some cases pain in the heart region of the type of angina pectoris without focal shifts in ECG are observed after a sudden onset of headache, dizziness, nausea, vomiting, and sometimes clearly focal symptoms of cerebral lesion.

Cerebro-renal crisis is an acutely developing insufficiency of cerebral circulation along with a neuro-reflex impairment of renal blood flow; *cerebro-abdominal crisis* is disorder of cerebral circulation combined with gastro-intestinal paroxysms; *cerebro-asthmoid crisis* is a disorder of cerebral circulation with a concomitant attack of dyspnoea without any signs of left ventricular insufficiency.

Disorders of venous circulation take the course like TDCC. They result in a venous congestion and increase of intracranial pressure. Milder cases are marked by headache ('the head is heavy', 'filled with lead') which occurs more often in the morning, the noise (hum) in the ears and head, oedema of the lower eyelid ('sacs' under eyes),

cyanotic shade of the face, ear lobules and mucous membranes. The cyanosis is first transient, and more evident with a patient in a lying position, and in unfavourable conditions of the surroundings (stuffy or hot). Veins are dilatated in the eye fundus. The condition is preceded by a feeling of weakness, rapid fatigue, malaise, low capacity for work, restless sleep. Loss of consciousness for 3-10 minutes with cooling and cyanosis of the limbs is common. Arterial pressure is either normal or decreased, venous pressure may sometimes be elevated (over 80 mm H_2O), but may be normal as well (between 55 and 70 mm H_2O). In more severe cases there is sharp cyanosis of the mucous membranes and the face, dilatation of the veins in the eye fundus, numbness and weakness in the limbs, short-time impairment of speech, double vision and other disorders of cerebro-cranial innervation, transient hemiparetic phenomena, hemianaesthesia, speech and consciousness disturbances, loss of orientation.

Characteristic features of disturbances of venous circulation are as follows: (a) diffuse nature of headache; (b) occurrence of headache sometimes in the morning, even immediately after wake-up, aggravation of headache when the head is turned aside, with a change in the atmospheric pressure or change in the environment temperature (when one comes from a warm room into a cold one or vice versa), after a period of excitation, alcohol intake, sexual excess; (c) prevailing dilatation of the retinal veins when the arterial calibre is within the normal range; (d) venous congestion in the mucous membranes of the eyes and lips.

Transient disorders of cerebral circulation in malignant course of hypertensive disease may occur as *cerebral oedema*. Elevation of arterial and intracranial pressure, venous hypertension, azotaemia and a rise in blood chloride content are important in the pathogenesis of acute oedema. The following symptoms develop in brain and meningeal oedema: acute headache going more painful with coughing, sneezing, nausea, and vomiting, vertigo, bradycardia, meningeal phenomena. One may often observe impairment of motion, coordination, speech, and epileptiform fits (in the form of eclamptic convulsions). The pressure of cerebrospinal fluid is elevated, the protein content is somewhat increased. The eye fundus reveals chocked disks, minor haemorrhages, venous dilatation, sometimes signs of albuminuretic retinitis, sometimes papiloedema. The amount of urine is decreased.

Transient disorders of cerebral circulation in hypertensive disease (*hypertensive cerebral crises*) are marked in most patients by additional elevation of arterial pressure, and only in some of the patients such crises set in independently of its changes. Various general crises are encountered more often; regional crises which are often attended with general cerebral symptoms are observed less frequently.

In most patients suffering from *atherosclerosis*, TDCC develop at standard arterial pressure; a smaller number of patients have it either increased or decreased. General cerebral symptoms and vegetovascular reactions are not so pronounced as in hypertensive disease. Among the regional dyscirculatory phenomena, the vertebrobasilar syndrome prevails, particularly Ménière-like paroxysms. General TDCC are easier in their clinical course and less persistent than in hypertensive disease.

Cerebrovascular crises in *arterial hypotensive disease* usually develop when arterial pressure is decreased. Arterial pressure in most patients with vegetovascular dysfunction is within the normal range throughout the crisis. General crises are most common, as well as Ménière-like ones. Crises with focal symptoms are encountered less frequently. The crises are marked by pronounced vegetative reactions, especially in cases of vegetovascular dysfunction.

Clinical course. A feature of TDCC is temporary character of cerebral disorders. According to the degree of the dyscirculatory phenomena TDCC are divided into mild TDCC of no more than 10 minutes, medium TDCC with pronounced clinical signs observed for a period from 10 minutes to several hours, and severe disorders leaving after a 24-hour period some insignificant neurological symptoms for a few days. After their sudden onset, the focal symptoms smooth out and disappear in several minutes or hours. Patients with recurrent TDCC, related to the same vessels, still have stable microsymptoms after disappearance of the focal symptoms, displayed by asymmetry of the nasolabial fold, deviation of the tongue, aniso-reflexia, mild sensory disturbances.

After an acute period, many patients, especially with TDCC in the vertebrobasilar system, note heaviness in the head, weakness, instability in walking, absent-mindedness, malaise, fatigue, emotional lability. Such a condition lasts for some period which depends on the clinical manifestations, severity of TDCC, individual features of the patient's organism, and the stage of the disease. In mild form of TDCC, the total period is up to a week on the average, in medium one up to two weeks, and in severe form up to three weeks. During the climacteric, the patients after TDCC are essentially asthenic, hypochondriac, their subjective sensations often disagree with objective data. In severe TDCC, a pronounced stage of the disease, high and stable arterial pressure, compensation is slower, and the compensation period is longer. The same goes for the cases when the doctor is called long after due time, or when medical treatment is not sufficient.

Follow-up studies reveal that almost two thirds of the TDCC patients have them recurrently. More obvious is now the role of some factors helping recovery and improving patient's state. Regular check-up and treatment afforded by the system of dispensary

care, as well as beneficial psychological and environmental conditions have proved to be effective. Favourable outcome occurs more often when the principal disease is less severe, and the patients are younger. Unfavourable outcome is associated with considerable severeness of the principal disease. In a number of studied cases, there was no improvement in spite of regular treatment and elimination of harmful effects. Recurrent TDCC in some patients directly follow nervous and psychic overstrain, sometimes they are coupled with an infection or intoxication or another disease, especially of the heart. Repeated TDCC often occur in women during the menopause.

3.5. Diagnosis

Identification of TDCC is sometimes difficult. There may be cases when some other disease is mistaken for TDCC. Therefore great care should be exercised to check up all the other systems and organs. In a lingering disease, the patient should be screened thoroughly by a team of medical experts. It is important *semiologically* that TDCC may not uncommonly occur in apparently healthy persons, and may be the first clinical manifestation of a cerebrovascular disease. It should be emphasized, however, that it does not suffice to detect a case of 'transient disorder of cerebral circulation' without an in-depth analysis of the principal disease which has brought it about. There are challenging cases where the basic diagnosis is established as the yield of special studies and more or less long observation.

Special methods of examination are important in diagnosing TDCC and revealing its pathogenic mechanism in each case. *Ultrasound flowmetry*, based on the Doppler effect, helps determine a decrease in the rate of the blood flow in the major head vessels, as well as parameters of collateral circulation. *Rheoencephalography* (REG) with functional tests reveals a change in the pattern of REG waves and marked asymmetry of the vascular response, a decrease of the blood volume often concomitant with an increase of the vascular tonus, great lability, instability of the vascular tonus and reaction and difficulty in the venous outflow. *Electroencephalography* shows both diffuse and local changes in cerebral biopotentials depending on the clinical form and degree of insufficiency of brain circulation. The *dye dilution method* reveals a lower rate of blood flow, decreased cardiac output. *Radiography* allows slowing down of tissue blood flow to be determined. *Electrocardiography* shows signs of coronary insufficiency, and sometimes pronounced disorders of coronary circulation. In TDCC patients with concomitant higher intracranial pressure, *echoencephalography* reveals signs of dilatation of the brain ventricular system by ultrasound. *Electromyography*

reveals a change in supersegmentary stimulation of the neuromotor apparatus. *Roentgenography* of the cervical vertebrae may reveal osteochondrosis and developmental anomalies. *Haemocoagulation* study establishes a rise in haemocoagulation activity in most patients with TDCC and in some patients these disturbances occur in the period between the crises. *Fibrinolytic activity* is mostly increased or normal. *Aggregation* of blood platelets is increased which leads to higher *blood viscosity* and *haematocrit* and worsens the blood rheological properties. Disorders of microcirculation of the blood are promoted by higher content of *organic acids* in blood, *hypoxaemia* and *changes in the blood acid-base equilibrium*. The blood content of *11-oxycorticosteroids* is increased. There are disorders in electrolyte, lipid, and carbohydrate metabolism, decrease in *total protein content* (*dysproteinaemia*), increase in free *adrenaline* and its oxidation products, *histamine*, and *acetylcholine*, and decrease in *cholinesterase* activity. Biochemical shifts might both follow the principal disease or result from metabolic disturbances of other origin; one should also consider possible non-specific or compensatory response of the organism.

Cerebral angiography is applied in patients with a tendency to TDCC, when progressive occlusion (stenosis, thrombosis), or morbid vascular tortuosity, developmental anomalies of the extracranial sections of the major head vessels and the aortic arch, etc., and also when an aneurysm or angioma are suspected.

Among the paroxysmal conditions which should be differentiated from TDCC are (1) migraine; (2) vestibular paroxysms (the Ménière syndrome, vestibular forms of encephalitis, vestibulopathy); (3) diencephalic crises in patients with a history of an internal craniocerebral injury; (4) adrenal crises (in pheochromocytoma); (5) paroxysmal conditions following various exogenous intoxications (with food, alcohol, carbon monoxide, drugs, etc.) or preuraemic states; (6) syncopal states after an over-due exposure to the sun; (7) epileptic fits; (8) apoplectiform development of a cerebral tumour or encephalitis; (9) hydrocephalic attacks; (10) vegetative paroxysms following stimulation of the sympathetic plexus of the vertebral arteries; (11) attacks of vomiting and headaches, accompanying vascular dystonia in patients, suffering from arachnoiditis of the posterior cranial fossa; (12) the Bruns syndrome in tumours of the posterior cranial fossa.

3.6. Treatment

Treatment during TDCC should be combined; one should apply every available drug and therapeutic means aiming at control of the vascular disturbances.

TDCC patients have to stay in bed until the acute period is over and for some more time depending on their general condition evaluated on the basis of both subjective and objective data. On the average, the patients have to stay in bed for 10 days in mild TDCC, for 15-17 days in medium TDCC, and for 22-25 days in severe forms. It is important not only to interrupt a developing crisis, but to prevent its possible recurrence. Eliminating harmful factors conducive to crises, one should make everything necessary to promote the compensatory process, and prevent recurrent decompensation of the vascular process.

Owing to the modern active therapeutic methods and the early, accurate and competent diagnosis of acute disturbances of cerebral circulation, it has now become possible to start TDCC treatment at the pre-hospital period, and admit the patients into hospital according to indications. Hospitalization is recommended for cases most dangerous with regard to cerebral stroke: (1) regional crises with focal symptoms, especially when the crises are repeated; (b) severe hypertensive cerebral crises with stable high arterial pressure, when treatment applied turns out to be ineffective; (c) the coronary-cerebral syndrome, suspicious for myocardial infarction or with prolonged angina pectoris.

The time factor plays a great part in TDCC treatment, and therefore in the prophylaxis of cerebral stroke.

The *treatment* of TDCC is conducted with due regard to possible pathogenic mechanisms, clinical manifestations of the crisis, and peculiarities of the principal disease. It is aimed at preventing recurrent TDCC and the prophylaxis of cerebral stroke. The main therapeutic principles are as follows: (1) to reduce high arterial pressure (in arterial hypertension); (2) to improve cerebral blood flow, microcirculation and collateral circulation; (3) to decrease high blood coagulability and to prevent aggregation of the formed elements; (4) to decrease permeability of the vascular walls; (5) to prevent cerebral oedema and bring down intracranial hypertension; (6) to improve cardiac activity and to raise arterial pressure (in cerebrovascular insufficiency); (7) to eliminate vegetovascular disorders; (8) to improve cerebral metabolism and to correct homeostasis.

The concept of *angiospasm and the failure of blood flow autoregulation in a sharp rise in arterial pressure* as one of the principal pathogenic mechanisms of *hypertensive cerebral crisis* stipulates application of spasmolytic, hypotensive, and anti-oedemic agents.

To lower arterial pressure and eliminate angiospasm, it is recommended to give: benzoclidine (Oxylidine), 1 ml of a 2 per cent solution subcutaneously or intramuscularly; vincamine (Devincan), 1 ml of an 0.5 per cent solution intramuscularly; bendazol (Dibazol), 2-3 ml of a 1 per cent solution or 6 ml of an 0.5 per cent solu-

tion intravenously; papaverine hydrochloride, 2 ml of a 2 per cent solution intravenously; dihydroethaverine (drotaverine, No-spa), 2 ml of a 2 per cent solution intramuscularly; aminophylline (Euphyllin), 10 ml of a 2.4 per cent solution intravenously in 20 ml of a 40 per cent solution of glucose or 1 ml of a 24 per cent solution intramuscularly; magnesium sulphate, 10 ml of a 25 per cent solution intravenously or intramuscularly; nicotinic acid, 1 ml of a 1 per cent solution intravenously with glucose; bencyclane furoate (Galidor, Halidor), 2 ml of a 2.5 per cent solution intramuscularly. Also effective are: Rausedil, 1 ml of an 0.1 per cent or 0.25 per cent solution intravenously or intramuscularly; diuretics: furosemide (Lasix), 2-4 ml of a 1 per cent solution intravenously or intramuscularly; etacrynic acid (Uregit), 0.05 g intravenously; neuroleptics: droperidol, 1-2 ml intravenously (to inject slowly) in 20 ml of isotonic solution of sodium chloride or in a 5-40 per cent glucose solution; clonidine (Catapresan, Haemiton), 1 ml of an 0.01 per cent solution intravenously or intramuscularly. A preparation of choice to arrest a severe hypertensive crisis is diazoxide (Hyperstat), 20 ml (300 mg), intravenously, and various combinations of beta-blockers, spasmolytics, saluretics (e.g. hydralazine with propranolol).

In very high and persistent arterial pressure without pronounced phenomena of cerebral and coronary atherosclerosis, it is recommended to apply: benzohexonium, 1 ml of a 2 per cent solution intramuscularly; azamethonium bromide or chloride (Pentamine), 1 ml of a 5 per cent solution intramuscularly; trimetaphan camphorsulphonate (Arfonad), an 0.05-0.1 per cent solution in a 5 per cent glucose or isotonic solution of sodium chloride, an average dose is 150-250 mg; lytic mixture of 2.5 per cent chlorpromazine (Aminazin)—2 ml, 2 per cent diphenhydramine (Dimedrol)—2 ml, 2 per cent trimeperidine (Promedol)—2 ml, intramuscularly or half the dose in 20 ml of a 40 per cent glucose intravenously (to inject slowly). After such an infusion the patients usually calm down and fall asleep. Tachycardia may occur, however (up to 120-140 beats per minute), as well as considerable decrease of arterial pressure (these phenomena in marked atherosclerosis may lead to development of both cerebral and myocardial hypoxia). To provide dilatation of cerebral vessels, carbogen inhalation is used (a mixture of 5-7 per cent carbon dioxide and 93-95 per cent oxygen). Leeches are recommended for strong headache. Procaine (Novocaine, Neocaine) is injected intramuscularly (5 ml of a 0.5 per cent solution) to influence venous circulation or to alleviate angiodystonic disorders.

To reduce permeability of the vascular walls and to strengthen them, 0.02 g rutoside (vitamin P, rutin) is given in combination with 2 ml of 5 per cent ascorbic acid intramuscularly, or 10 ml of

10 per cent calcium gluconate intramuscularly or intravenously.

Dehydrating therapy is indicated in a crisis with signs of cerebral oedema: furosemide (Lasix), etacrynic acid (Uregit).

The treatment of *atherosclerosis* patients during transient disorders of cerebral circulation is aimed at improvement of cardiac function and normalization of arterial pressure until it is optimal (in cerebrovascular insufficiency). Weakened cardiac function is treated with convallaria glycosides (Corglycon), 1 ml of a 0.06 per cent solution in 20 ml of 40 per cent glucose; strophanthin, 0.25-0.5 ml of an 0.05 per cent solution with glucose intravenously and cordiamin or camphor subcutaneously. Arterial hypotension is treated with 1 ml of 10 per cent caffeine subcutaneously, 1-2 ml of 1 per cent phenylephrine (Mezaton) subcutaneously or intravenously, 0.5-1.0 ml of 5 per cent ephedrine subcutaneously.

Combined cerebrocoronary crises are treated with nitrites, menthyl valerate (Validol), Corvalol; severe anginal attacks should be treated with morphine with atropine, trimeperidine (Promedol) with diphenhydramine (Dimedrol), noramidopyrine methane sulphonate (Analgin) with promethazine (Pipolphen) or Dimedrol, as well as according to indications with ATP, Inosie 'F', carbocromen (Intensain), amiodarone (Cordarone), verapamil (Isoptin), Hyalurhythmal. Vasoactive preparations are also applied: aminophylline (Euphylline), 10 ml of a 2.4 per cent solution with glucose intravenously; xantinol nicotinate (Complamin), 0.25 g 3 times a day or 2 ml intramuscularly; Nicospan, 0.1 g 3 times a day; Instenon, 1-2 dragées 3 times a day, 2 ml intramuscularly or intravenously (to inject slowly); cinnarizine (Stugeron), 0.025 g 3 times a day; Vincaton (Vincapan), 0.01 g 3 times a day; Desclidium, 0.1 g 3 times a day; in elevated arterial pressure papaverine or drotaverine (No-spa) is given.

To improve microcirculation and reduce aggregation of blood formed elements, the recommended drugs are Parmidin (Prodectin), 0.25-0.5 g 3 times a day; Rheopolyglucin, 500 ml intravenously in a drip.

In transient disorders of cerebral circulation with focal symptoms and the cerebrocoronary syndrome, patients with elevated prothrombin index should be given anticoagulants: phenindione (Phenyllin), 0.03 g 1-3 times daily; Acenocumarol (Sincumar), 0.004 g 3-4 times daily. The prothrombin index should be checked regularly (it is reduced down to 65-60 per cent and even to 45 per cent for in-patients) as well as the urine condition. Contraindications for anticoagulants are haemorrhages, defect of blood clotting factors, kidney and/or liver insufficiency, arterial hypertension over 200 mm Hg, gastric ulcer, diabetic retinopathy, febrile state. Acetylsalicylic acid (Aspirin), 0.5 g 3 times a day, is given to prevent

aggregation of blood formed elements, especially to patients with intermittent ischaemia.

In *strong headache*, noramidopyrine methane sulphonate (Analgin) with promethazine (Pipolphen), Spasmoveralgin, Sedalgin are prescribed. The vertebrobasilar dyscirculatory syndrome with vertigo, nausea, vomiting, hiccup is treated with atropine, 1 ml of a 0.1 per cent solution subcutaneously; droperidol, 1-2 ml of a 2.5 per cent solution or 1 ml in 20 ml of 40 per cent glucose intramuscularly; chlorpromazine (Aminazin), 1-2 ml of a 2.5 per cent solution intramuscularly; diazepam (Seduxen), 2-4 ml of an 0.5 per cent solution intramuscularly; thiethylperazine (Torecan), 1-2 ml intramuscularly.

In vertigo belladonna (*Atropa belladonna*) extract in combination with Nicospan or No-spa, camphor bromide, phenobarbital (Luminal) and bromisoval (Bromural) are used, as well as thiethylperazine (Torecan), a lozenge, 2-3 times or a suppository 2 times a day; Belloid; Belloid with Bellaspon (Bellataminal); Billergal; cinnarizine (Stugeron) with clemastine (Tavegil); bumethan sulphate (Bupatol) 12.5-25 mg 3-6 times a day. Between attacks, patients with cervical osteochondrosis and/or the radicular syndrome are treated with Scutamil 'C', 0.25 g 3 times a day after meals; diadynamic currents, electrophoresis with potassium or magnesium iodide, massage for the cervicocollar area.

To improve cerebral metabolism, 4-aminobutyric acid (Gammalon, Aminalon) is given, Ceremon, Cerebrolysin, Apoplectal, Lipobolite, meclofenoxate (Lucidryl), as well as Cogitum, Herioptil, Herontic, Senton, Decamevit, Calcvita, Vibalt, Otoneirin, and vitamins of the group B.

Antisclerotic therapy is indicated, including such preparations as clofibrate (Miscleron, Atromidin); clofibrate with androsterone (Atromid) 'C'; Lipostabil, etc.

Sedatives and tranquillizers are given: bromine in various dosages, valerian, Passit, Valosedan, diazepam (Seduxen), Tazepam, trimetozine (Trioxasin), meprobamate, chlordiazepoxide (Librium), laevomepromazine maleate (Nozinan, Minozinan), opipramol (Insidon).

Treatment of pronounced vegetovascular dysfunction aims at lowering the excitability of the vegetative centres and elimination of angiodystonic disorders. Effective medications for that are injections of diazepam (Seduxen), diphenhydramine (Dimedrol), promethazine (Pipolphen), alimemazine (Teralen), adiphenine with tolazoline (Priscophen), ipronal (Vasalgin), dimetotiazine (Migristene), methysergide (Deseril) retard, pizotifen (Sandomigran), cyproheptadine (Peritol) for treating headache, thiethylperazine (Torecan), Belloid, Belloid with Bellaspon (Bellataminal), Billergal for vertigo and also Patrin 'D'. Insomnia is treated with

valerian preparations, Valocordin, such tranquillizers as diazepam (Valium, Seduxen), laevomepromazine maleate (Tisercin, Nozinan), etc., as well as nitrazepam (Eunoctin, Mogadon, Radedorm), lorazepam (Ativan), vinilbital (Speda, Optanox), Tardyl.

In case there is no success in medication treatment of a patient with transient disorders of cerebral circulation due to abnormality in the extracranial segment of major vessels of the head, a possibility for surgical intervention is discussed. Angiography is carried out before an operation. *Indications for surgical treatment* of TDCC are as follows: (1) stenosis of the carotid artery with TDCC or with stable but mild focal symptoms of brain dysfunction; (2) acute occlusion of the carotid on the neck with marked focal symptoms but without consciousness disorder, in the first 6-12 hours; (3) abnormal tortuosity of the carotids; (4) atherosclerotic occlusion and stenosis of the vertebral arteries at the site of their origin; (5) abnormal branching of the vertebral arteries proper; (6) proximal occlusion of the subclavian artery; (7) compression of the vertebral artery with osteophytes.

3.7. Prognosis

It is essential to estimate probability of the development of cerebral stroke in every case of TDCC. In prognosis, the peculiarities of cerebrovascular disease are important with regard to possible stroke. The prognosis is unfavourable in hypertensive disease with stable high arterial pressure, especially diastolic one, concomitant with pronounced ophthalmoscopic changes. In atherosclerosis, the prognosis is also unfavourable in patients with pronounced cardiovascular abnormality combined with changes in the fundus of the eye. The nature of clinical manifestation and frequency of TDCC are important in prognosis along with the background disease.

Cerebral stroke may follow a TDCC onset: after a crisis with dyscirculatory phenomena in the internal carotid system and/or the brain stem—in several hours, days, months, sometimes years; after a general crisis (with general cerebral symptoms only)—in several months, more often in a year or a longer period. The most favourable prognosis may be given in a crisis which is similar to the Ménière syndrome; it is less favourable in a general crisis; the worst prognosis—in the carotid dyscirculatory syndrome and dyscirculatory phenomena in the brain stem. In atherosclerosis, especially unfavourable are TDCC, rapidly following each other in a sequel, which is an early warning of a possible stroke.

In case of arterial hypotension and vegetovascular dysfunction, a cerebrovascular crisis is seldom dangerous with regard to stroke.

But prognosis is quite opposite in arterial hypotension combined with atherosclerosis. Cerebrovascular crisis in patients with arterial hypotension and atherosclerosis should be regarded as rather dangerous, since such a crisis may be a prodrome of a stroke.

However, the occurrence of TDCC themselves does not necessarily mean an imminent stroke. TDCC occur far more often than cerebral strokes. But frequent, medium or severe, general and regional TDCC may contribute to morbid development, impair neural and psychic function, and eventually lead to disablement.

3.8. Capacity for Work

Correct *assessment* of patient's working capacity may have its influence on the prognosis. When a TDCC occurs, patients should be considered as temporary disabled. On the average, the period of disability after a light crisis is up to 15 days, up to 26 days after a medium one, and up to 41 days after a sereve crisis. Every single case should be judged separately, with due regard not only for the severity, but for the clinical manifestations of the crisis, as well as for objective and subjective appraisal of the patient's status after the crisis, the nature of the course, and stage of the vascular disease, not to mention the occupational conditions.

The character and course of the principal vascular disease, residual physical weakness, the efficaciousness of treatment and occupational conditions are the decisive factors in evaluation of further working ability.

Rational job placement is needed in frequent recurrent crises, so that there would be no further mental and physical strain or much responsibility and quick decision making. Special attention in this respect should be drawn to patients suffering from severe recurrent crises entailing impairment of neural and mental function.

3.9. Prophylaxis

Long-term observation of patients shows that cerebrovascular crises may occur long before the incipience of any marked lesion in cerebral vessels and more severe complications. First, functional angiodystonic cerebral crises occur which further on are gradually changed by 'organic' crises and play a certain part in the progress of disease. Therefore the prophylaxis of cerebral crises in both early and pronounced stages of vascular disease prevents further development of the morbid process in the brain.

TDCC prophylaxis includes primarily measures to provide the early diagnosis and treatment of the principal disease —hypertension, atherosclerosis, infectious and allergic vasculites, etc. Patients with TDCC require special prolonged observation by a neurologist and regular treatment within the framework of special dispensary care.

Factors, which have possibly contributed to development of disturbances of cerebral circulation, and influence of occupational and life conditions are to be found out. The patients are advised on the mode of their work and rest, nutrition, etc. They are examined by a therapeutist, ophthalmologist, and other medical specialists. On the basis of the examination and due consideration of the above-mentioned factors an individual plan of prophylaxis and therapy is compiled. It includes maintenance and preventive treatment, prophylactic hospitalization, sanatorium (or resort) treatment, job placement and various kinds of social and every day assistance.

The experience of such care is positive. Correct regulation of work, rest, nutrition, sleep, detection and elimination of risk factors (if possible), regulation of arterial tension and biochemical indices bring favourable results. Treatment with antisclerotic, vasoactive, hypotensive, cardiac drugs, anticoagulants, antiaggregants, metabolic preparations, vitamins, etc., as well as remedial exercise, walks, sanatoria and resorts, help put down the incidence and even eliminate transient disorders of cerebral circulation.

Chapter 4. Cerebral Stroke

4.1. Introduction

Cerebral stroke (L. *insultus*, *apoplexia cerebri*) is an acute disorder of cerebral circulation.

According to the WHO data, the incidence of new cerebral stroke cases varies annually within 1.27 to 7.4 per 1000 population which depends to a certain degree on the age of the surveyed persons. The incidence of stroke in the USA has been found to be 2.6 cases per 1000 population. In Japan, hemiplegia and other symptoms indicating a case of stroke in the past rates 15.7 per 1000 population. As to the Soviet Union, the data of the Research Institute of Neurology of the USSR Academy of Medical Sciences show that signs of a stroke suffered in the past were observed in 20.8 per 1000 in a sample group of males 50-59 years of age.

The structure of cerebrovascular lesions has changed for the past decades owing mainly to increase of the ischaemic forms. The Research Institute of Neurology of the USSR AMS has analysed the data by a number of clinics; the number of softening of the brain exceeded haemorrhages by 23 per cent in 1963, and by 32 per cent in 1969. In the UK, the mortality rate due to cerebral haemorrhages in the thirties exceeded that due to softening of the brain more than two-fold while the mortality rate from softening of the brain now exceeds that from haemorrhages.

The incidence of cerebral strokes increases with age: it is 7.4 per 1000 population in the age group of 50-59 years, and 20.0 per 1000 population in the age group of 60-69 years. In Europe, cerebral stroke affects a million people annually.

Mortality due to cerebral stroke is also high: in Europe it is 12.5 per cent of the total mortality. According to the WHO data, cerebral stroke causes death in slightly less than half of the patients in a month's time after the onset, nearly 50 per cent of those survived die in the next 3-4 years. Stroke is followed by a state of complete disability in 75 per cent of patients; only 13 per cent of them are capable of resuming their occupation.

4.2. Risk Factors

Risk factors of cerebral stroke are as follows: (1) genetic predisposition to vascular diseases and disturbances of cerebral and coronary circulation; (2) hyperlipidaemia due to lipid metabolic disorder; (3) arterial hypertension; (4) hyperglycaemia; (5) obesity; (6) insufficient physical activity; (7) smoking; (8) age (the incidence of stroke rises with age); (9) the period of development and the course of vascular disease (recurrence of regional cerebrovascular crises); (10) features of habitus (especially pyknic); (11) mode of life and nutrition (a positive correlation has been established between consumption of cereals and sugar and mortality rate due to cerebrovascular lesions); (12) repeated stress and prolonged neuropsychic overstrain. A combination of three or more harmful factors increases the risk of stroke.

4.3. Classification

According to the nature of the pathological process, two major groups of cerebral stroke may be distinguished: *haemorrhagic* and *ischaemic* ones.

Haemorrhages into the brain matter (*parenchymatous*) and cerebral meninges (*subarachnoid, subdural, epidural*), as well as their combined forms (subarachnoid-parenchymatous or parenchymatous-subarachnoid, parenchymatous-ventricular, etc.) are related to haemorrhagic stroke.

Ischaemic stroke includes *thrombotic, embolic* and *nonthrombotic* varieties. Cerebral infarction due to *complete occlusion* of an *extra-* or *intracranial vessel* because of thrombosis, embolism, obliteration of the vessel by an atherosclerotic plaque or other causes is considered to be *thrombotic* or *embolic strokes.* In incomplete occlusion of a vessel, a *non-thrombotic stroke* may arise, more often due to an atherosclerotic lesion, angiospastic state, vessel tortuosity, cerebrovascular insufficiency. *Combined forms of stroke* are sometimes observed: a combination of haemorrhagic and ischaemic foci, e.g. subarachnoidal haemorrhage and cerebral infarction.

4.4. Aetiology

Cerebral stroke most commonly occurs in hypertensive disease, in arterial hypertension due to a kidney lesion, pheochromocytoma or some of the endocrine disorders; in atherosclerosis affecting major cerebral vessels in the neck, intracranial vessels and/or in their

simultaneous affection; atherosclerosis is often concomitant to hypertensive disease or arterial hypertension or diabetes mellitus. Less often the cause of a stroke may be rheumatism, various types of vasculitis (syphilitic, allergic, obliterating thrombangiitis, Takayasu's disease, etc.), an aneurysm, blood diseases (aplastic anaemia, erythraemia, leucosis, thrombopenic purpura etc.), acute infection, septic condition, a cerebral tumour, a malignant tumour, intoxication, carbon monoxide poisoning, congenital heart disease, myocardial infarction, toxicosis of the second half of pregnancy, eclampsia, diabetes mellitus, a trauma of the major cervical vessels, arterial thrombosis following an aneurysm rupture. Sometimes a stroke may occur during or after a heart operation performed for congenital or acquired heart disease. Among the other causes there may be cervical osteochondrosis with atherosclerotic changes in the vertebrobasilar system, vascular anomalies, in particular congenital tortuosity of the major arteries of the head and neck.

4.5. Pathogenesis

A number of factors are important in the pathogenesis of stroke: (1) disturbed neural regulation of cerebral circulation which results in a persistent spasm, paresis or paralysis of intracerebral arteries and arterioles; (2) morphological vascular changes leading to decrease in the patency of the brain-supplying arteries; occlusive lesions in major vessels and cerebral vessels, extravasating compression of arteries, their deformation, anomalies of larger cerebral vessels and asymmetry of the origination of smaller branches, irregular form and configuration of the vessels; (3) insufficiency of collateral circulation; (4) failure of cerebrovascular autoregulation in response to variation of perfusion pressure or due to changes in vasodilatation and vasoconstriction effects (in considerable decrease of oxygen saturation of the blood and increase of carbon dioxide tension in the brain, metabolic acidosis, etc.); (5) impairment of general haemodynamics; (6) changes in biochemical and physicochemical properties of the blood (increase in viscosity, adhesion and aggregation of blood formed elements), disturbance of the redox processes (accumulation of incompletely oxidized metabolites, disproportion in electrolyte contents); (7) vascular crises in arterial hypertension resulting in a spasm, paresis or paralysis of intracerebral arteries and arterioles. In this last case permeability of the vessels increases and exudation of plasma through the vascular wall (intramural plasmorrhagia), erythrodiapedesis (intramural haematomas, perivascular haemorrhages) occur. Then cerebral oedema develops, thus causing increased resistance in microcirculation,

which results in slowing down of cerebral blood flow and hypoxia. Due to angioparesis and imbibition of the vessel wall by protein substances and erythrocytes, the wall necrotizes, blood oozes through affected walls into the surrounding tissue, the walls begin to rupture, and may finally break.

The pathogenesis of disturbances of cerebral circulation is complex and varied; there is commonly an interplay of several factors, the leading ones being hypoxia and ischaemia of cerebral tissue.

Haemorrhagic stroke often develops either when there is a *vessel rupture* or as a consequence of *neurogenic vasomotor disorders*, giving rise to prolonged cerebrovascular spasm, which in its turn causes deceleration of blood flow and hypoxia of brain tissue. Vascular dystonia (widening of the lumen or uneven calibre) and higher permeability of the vessel wall lead to exudation of plasma, perivascular oedema and diapedetic haemorrhages. Ring-like haemorrhages are not infrequently found around an affected vessel; small perivascular haemorrhages merge and form a vast haemorrhagic focus. Due to the cessation of normal circulation and consequent disorder of the chemism of the nervous tissue (a rise in the acidity contributes to necrosis), and to the erythrodiapedetic haemorrhages, a focus of nervous tissue imbibed with blood components forms.

Rupture of an abnormal vessel wall usually occurs when there is a sharp change (a steep rise) in arterial pressure; it leads to formation of a haematoma. The possibility of a rupture is higher when the vessel wall becomes distinctly thinner due to atherosclerosis, when there is destruction of the wall in vasculitis, necrosis of a miliary aneurysm. If the wall is ruptured, blood may spread from the focus along the perivascular space, and perivascular haemorrhage may be thus observed at a distance from the rupture. In an aneurysm rupture, as well as in a large rupture of a vessel, the haemorrhage may be abundant, and an intracerebral haematoma may develop with a break into the subarachnoid space and or cerebral ventricles.

Ischaemic non-thrombotic stroke follows the *mechanism of cerebrovascular insufficiency*, when a critical decrease of brain blood flow results either from disorder of general haemodynamics or from breakdown of autoregulation of cerebral circulation in the presence of stenosis, occlusion or abnormal tortuosity of a larger extra- or intracranial cerebral vessel. The stroke may also occur due to *prolonged angiospasm* or *blood stasis* following impairment of neural regulation of vascular tonus.

Breakdown of autoregulation of cerebral vessels, occurring in the period of additional rise in arterial pressure, appears to be important in the pathogenesis of microfocal cerebral infarctions in hypertensive patients. Experiments have established that when the carotid is ligated, the blood in the veins of the contiguous zone

of circulation becomes cyanotic (resulting from inadequate oxygenation). Combination of hypoxia with a decrease in arterial pressure may lead to development of foci of softening even when there is no change in the vessel walls, especially in the cerebral cortex, which is the most responsive to decrease of arterial pressure. An oedema forms around a focus of white (anaemic) softening, and small haemorrhages (erythrodiapedesis) are often found there.

Some writers believe that ischaemic stroke, which is considered to be non-thrombotic, may also develop due to thromboembolism, but no occlusion is observed because of 'recanalization' of the artery by the moment of study.

Ischaemic thrombotic stroke develops due to *thrombosis*. Thrombosis in its turn is facilitated by an *abnormal change in the artery walls* (overgrowth of the intima, ulceration, epithelial injury, atheromatous plaques narrowing the lumen), *increased coagulation activity and viscosity of blood, changes of the protein ratio* due to an increase in albumin contents, *disorders of haemodynamics*, a decrease in cardiac activity and arterial pressure, deceleration of cerebral blood flow, angiodystonic changes in the vessels. A gradually growing thrombus may occlude a vessel lumen completely, which leads to malnutrition of brain matter and development of ischaemic softening of the brain. The thrombus stimulates angioreceptors, which results in paresis of the vessel wall; an oedema of the surrounding tissue develops in response.

Ischaemic embolic stroke may follow occlusion of a cerebral artery with an *embolus*. Blood flow may carry into the brain particles of parietal thrombi and verrucose layers in valvular heart disease, especially in stenosis of the mitral valve and aortic valve failure; in recurrent rheumatic endocarditis, subacute or bacterial endocarditis; in congenital valvular heart disease or during an operation performed for either congenital or acquired valvular heart disease; in myocardial infarction, acute postinfarction myocardial aneurysms; cardiosclerosis or myocarditis with atrial fibrillation and formation of parietal thrombi. Particles of the parietal thrombi and disintegrating atherosclerotic plaques in the ascending part and arch of the aorta or in the major head vessels may become the source of embolism. In some cases an embolus originates in the veins of the systemic circulation (in thrombophlebitis of the limbs, the abdominal cavity or the small pelvis, etc.) due to a patent foramen ovale. Cerebrovascular embolism may also occur in bronchiectatic disease, empyema, a cavern, abscesses in the lungs, malignant tumour, a general infectious disease. Fat embolism is encountered following fractures of the long tubular bones or due to an operation involving extensive trauma of subcutaneous fat. Gas embolism occurs in lung operations, in pneumothorax, or after work under pressure (caisson disease). The pathogenesis of cerebrovascu-

lar embolism is influenced by the obturation factor, extensive innervation disorders due to mechanical stimulation of the receptors in the vessel wall by an embolus (spasm of the vessels with their subsequent paralytic dilatation); fragmentation of the embolus may occur in the process, and it may be dislodged into some distal segment or small branches of the vessel, which often results in microfocal haemorrhages into already ischaemized tissue, giving rise to a *haemorrhagic cerebral stroke* or a *mixed infarction.*

Anaemic cerebral infarct is more common. Gray matter (the cerebral cortex and subcortical ganglia) is affected predominantly. Embolism in the carotid system occurs more often than in the vertebrobasilar system. Sometimes multiple embolism is observed in different brain vessels. In embolism of a cerebral artery, blood supply in the corresponding zone of vascularization is disturbed. In distant cortical branches capillaries become dry, the walls of the arteries invaginate into the lumina, the lumen grows uneven and the vessels become tortuous due to dystonia and brain oedema develops. In case the reflectory spasm ends and the embolus moves further, the blood flow in the artery restores and is switched off in only small cortical branches. An infected embolus may lead to an inflammatory complication.

The **role of collateral circulation.** The extent of a cerebral infarct and severity of concomitant clinical symptoms depend on collateral circulation which takes over at the moment when blood flow in a cerebral vessel is disturbed. Collateral circulation is most effective during a gradual occlusive process in the extracranial vessels of the brain: it is carried out mostly through the circle of Willis. Therefore even complete occlusion of the internal carotid may sometimes occur without clinical symptoms. Collateral circulation is more limited in case the circle of Willis is plugged somewhere or intracranial vessels are occluded. Substituting collateral circulation through the corticomeningeal anastomoses is often not sufficient. However, these anastomoses are sometimes important, and they are capable of preventing an extended brain infarction even in occlusion of the main trunk of the middle cerebral artery; neurological symptoms may be insignificant in that case. Collateral circulation potential is lower in case of combined lesion in the major arteries of the head and intracranial vessels; it is still lower in older persons who have diffuse sclerotic changes of the vascular wall due to age apart from atherosclerosis of the cerebral arteries.

The **phenomenon of 'stealing'.** There may be a relative circulatory insufficiency in the area of a vessel providing collateral blood supply to the affected territory (the phenomenon of 'stealing').

Several forms of the steal syndrome are distinguished. In the subclavian steal syndrome due to occlusion of the initial part of the subclavian artery, the vertebral artery of the affected side be-

comes a collateral to the arm, where the blood flows from the vertebrobasilar system into the arterial system of the arm in the reversed direction to the detriment of the brain. When the arm is exercised much, blood supply to the brain becomes less, and due to that some brain-stem or other symptoms may appear.

In ischaemic stroke, vasodilatative and vasoconstrictive arterial response in the damaged area is either absent or sharply reduced. Hence, vasodilatating stimulation results in increased blood inflow only into intact brain areas to the detriment of blood flow of the affected segment (the *intracerebral steal syndrome*). Conversely, vasoconstrictive stimulation, reducing blood supply to the unaffected brain areas around the foöus of affection, elicits redistribution of blood into the focus (the 'Robin Hood syndrome').

4.6. Pathological Anatomy

Severity of damage to the brain substance due to stroke varies from changes in some structural elements of the neural tissue to formation of vast foci with gross anatomical destruction.

Ischaemic stroke leads to *infarcts* which may be *white*, *red*, and *mixed* ones. In haemorrhagic strokes there are *haemorrhages of the type of haematoma* and *seeping haemorrhages*. A special group includes *haemorrhages due to rupture of a congenital aneurysm of cerebral vessels*. Disorders of cerebral venous circulation, the symptoms of which are sometimes very much like those of stroke, deserve special consideration.

Haemorrhagic strokes as a rule occur in diseases with high arterial pressure. This is due to the fact that vascular crises characteristic of hypertensive disease and arterial hypertension bring about morphological changes in the walls of intracerebral vessels with disturbances in their permeability—seeping with plasma (Fig. 19), necrosis (Fig. 20), microaneurysms (Fig. 21) and their rupture. The rupture of arterial or arteriovenous aneurysms may occur in normal blood pressure.

Prevailing localization and the nature of haemorrhages are determined by peculiarities of angioarchitectonics of the various brain parts. In hypertensive disease, the vessels of the subcortical ganglia and the thalamus are affected most of all; this is due to perpendicular origination of deep branches from the middle cerebral artery which is a continuation of the internal carotid, and to a small number of anastomoses in the area. Due to that, postmortem examination most often (in 40 per cent) reveals haemorrhages in the subcortical ganglia, with involvement of the adjacent white substance (so-called *lateral haemorrhages*, i.e. located laterally with respect

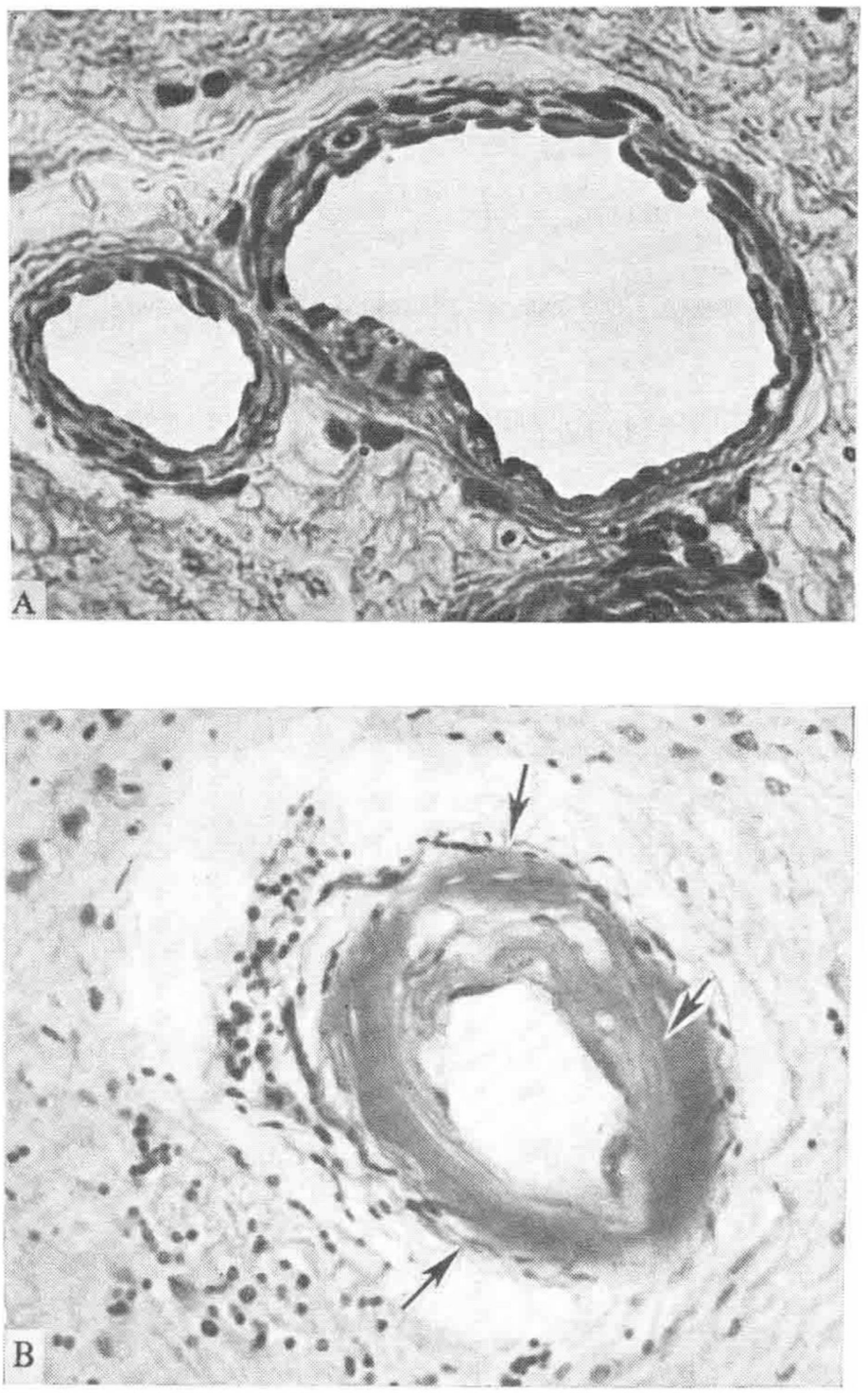


Fig. 19. Micropreparations of the brain tissues stained with haematoxylin-eosin.

A—normal structure of the vascular wall of the arteries of small and medium calibre in the subcortical ganglia of the man's brain (given for comparison); X400
B—plasmodic impregnation of the wall of a small artery (shown by the arrows) in the subcortical ganglia; X200

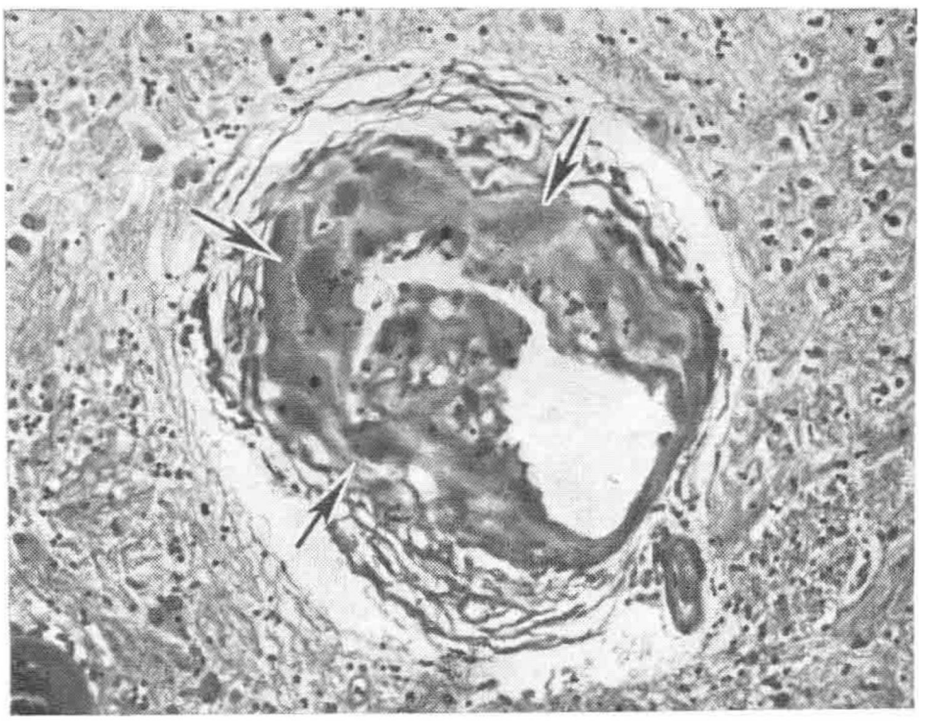


Fig. 20. A micropreparation of the brain tissue with fibrinoid necrosis of the wall of a small artery in the area of a miliary aneurysm; stained with haematoxylin eosine; X200.

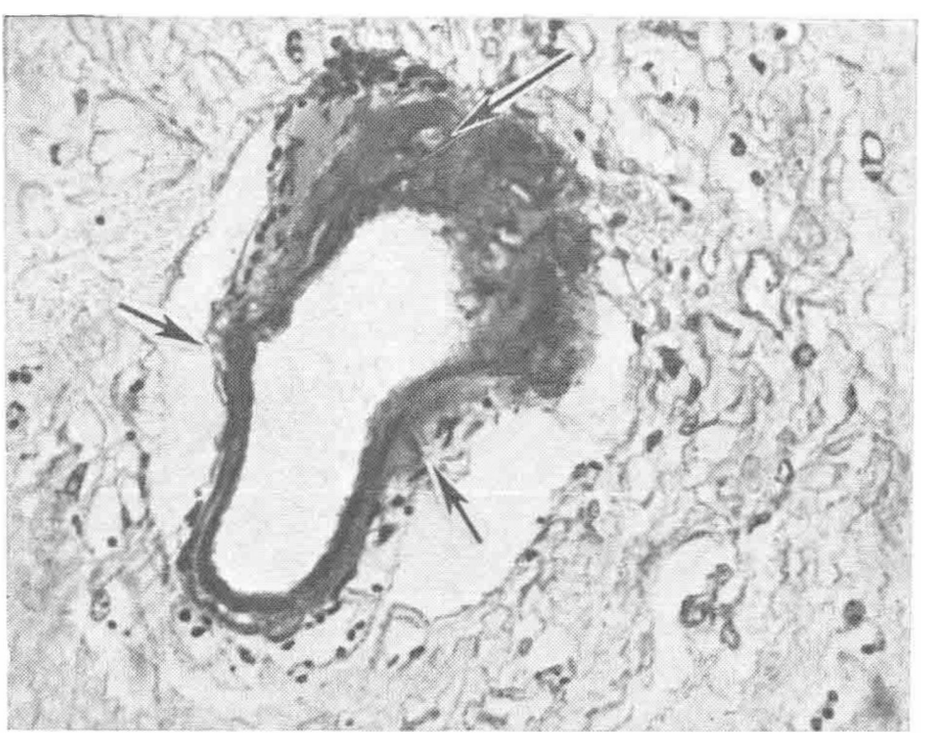


Fig. 21. A micropreparation of the brain tissue with an aneurysm-like extension of a small artery (the microaneurysm is shown by the arrows); stained with haematoxylin eosine; X200.

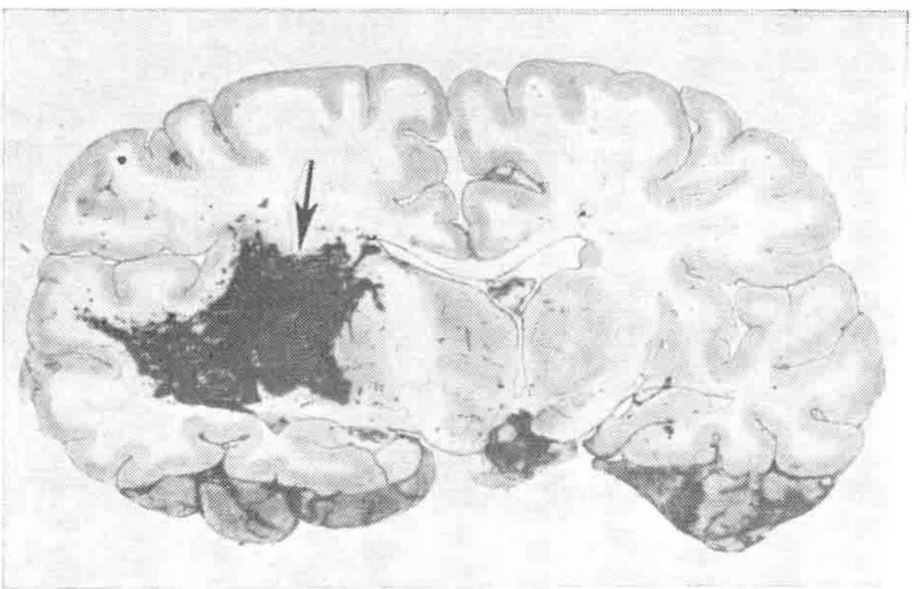


Fig. 22. A frontal section of the brain at the level of the thalamus with 'lateral' haemorrhage (haematoma is shown by the arrow) in the left cerebral hemisphere.

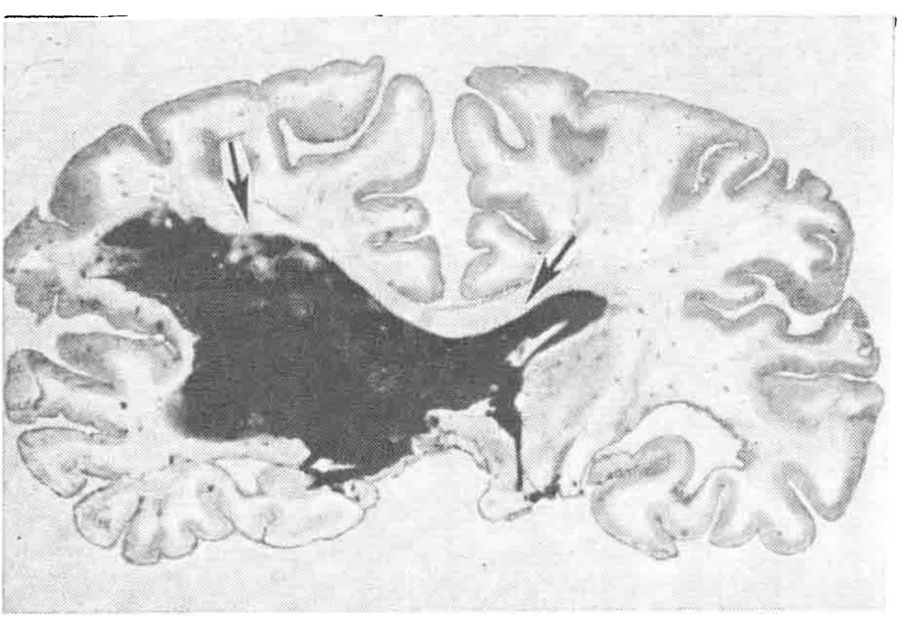


Fig. 23. A frontal section of the brain at the level of the thalami with extended 'mixed' haemorrhage in the left hemisphere with extravasation of blood into the ventricles (the haematoma is shown by the arrows).

to the internal capsule, Fig. 22); vast haemorrhages destroying subcortical ganglia, internal capsule, and thalamus (so-called *mixed haemorrhages*, Fig 23) rank second (16 per cent); haemorrhages into the thalamus (so-called *medial* haemorrhages, Fig. 24) comprise 10 per cent; those into the *cerebellum* — 6-10 per cent; those into the *brain stem*, predominantly into the *pons*, 5 per cent of the total number of intracerebral haemorrhages. Haemorrhages into the white substance of the cerebral hemispheres are very rare. Subdivi-

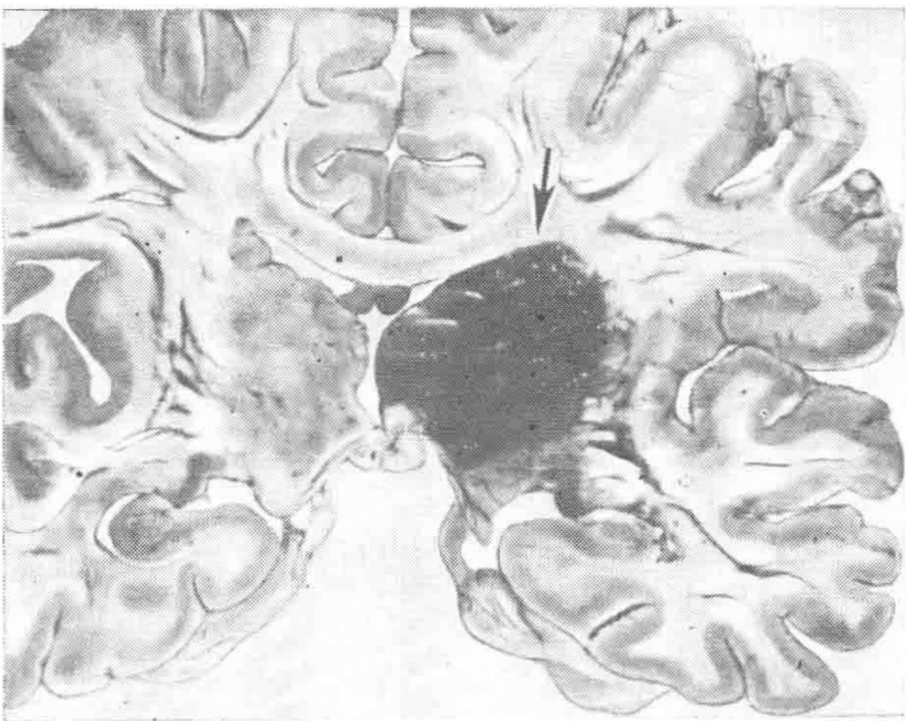


Fig. 24. A frontal section of the brain at the level of the thalami with haemorrhage into the right thalamus (the arrow shows a 'medial' haemorrhage).

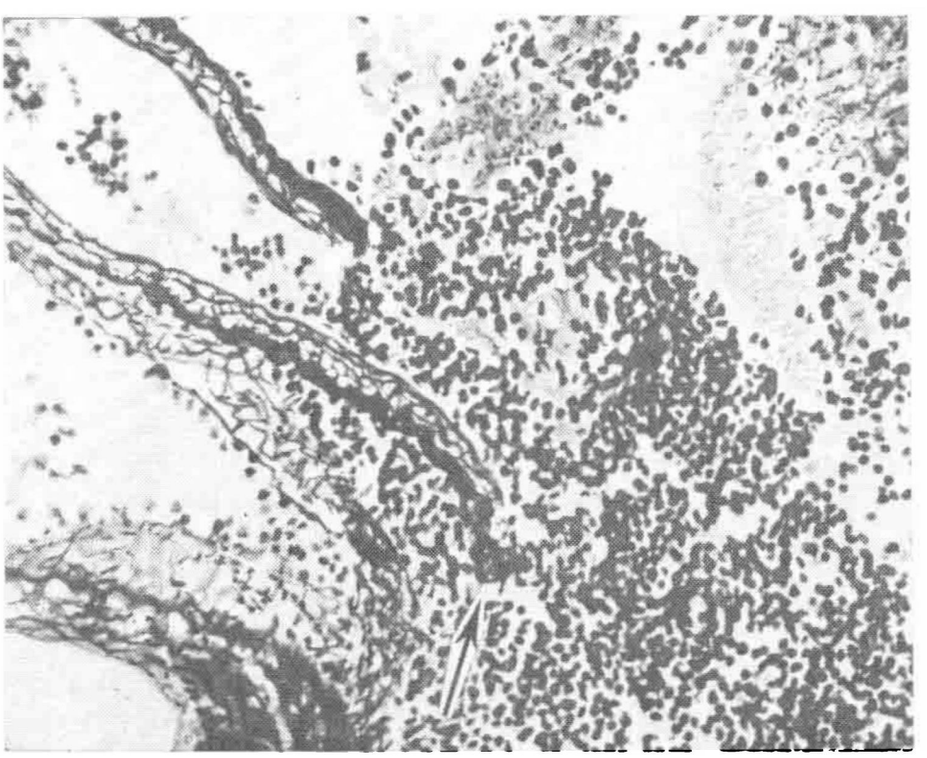


Fig. 25. A micropreparation of the brain tissue with a rupture of a vessel (shown by the arrow); impregnation according to Snesarev; X200.

sion of hemispheric haemorrhages into *lateral*, *medial*, and *mixed* are important for surgical treatment of haemorrhagic stroke.

Haemorrhages of the type of *haematoma* are attended with formation of a cavity containing fluid blood or blood clots, and they constitute 85 per cent of all intracerebral haemorrhages. They most commonly develop in subcortical ganglia, and less so in the cerebellum. Rupture of an abnormally changed vessel (Fig. 25) is the principal mechanism in the development of haematoma. Then blood begins to exert pressure on brain substance, dislocating some of its areas, which is possible because of the spare space (the ventricles, subarachnoid space). The size of such a haematoma exceeds the volume of substance destroyed by blood in the process, but compression of the adjacent brain parts is insignificant; it is essential only in haemorrhages into the cerebellum due to the anatomical features of the posterior cranial fossa (Fig. 26).

Haemorrhages of the type of *imbibition* occur mainly in the thalamus, less often in the pons, and account for 15 per cent of intracerebral haemorrhages. They are the result of fusion of small foci of haemorrhages produced by diapedesis from smaller vessels. They are red-coloured, of flabby consistency and in appearance may sometimes remind a haemorrhagic infarct. In the first hours of the stroke, the permeability of the vessels, bordering the haemorrhage, is disturbed, and an oedema develops; the blood spreads along the nerve fibres. Leucostasis and leucodiapedesis are brought forth towards the end of the first 24 hours, the size of the focus is increased due to diapedetic haemorrhages and necrobiotic changes in the oedematous brain substance. In two days the reparation process begins, i.e. granular globules, hypertrophic astrocytes appear, and later a swelling of astroglias and newly-formed vessels; the blood is subject to haemolysis, and macrophages with haemosiderin, argyrophilic and collagenic fibres are formed. The outcome of the haemorrhage may be a gliomesodermal scar or a cyst containing haemosiderin (Fig. 27).

In 80-85 per cent of haemorrhages, autopsy reveals a breakthrough of blood into the ventricles, and very rarely into the subarachnoid space where blood may also penetrate from the fourth ventricle. Primary ventricular non-traumatic haemorrhages are very rare phenomena. Primary subarachnoid haemorrhages arise after a rupture of congenital aneurysms in the arteries of the base of the brain. They are mainly localized on the basal surface or in the Sylvian sulcus; blood sometimes penetrates into the subdural space; brain substance is often damaged (subarachnoid-parenchymatous haemorrhages). Localization of the resulting haematoma depends on the localization of the aneurysm; usually that is the basal part of the frontal lobe or the temporal area. It is possible to observe sometimes an extensive inflow of blood into the ventricles (Fig. 28)

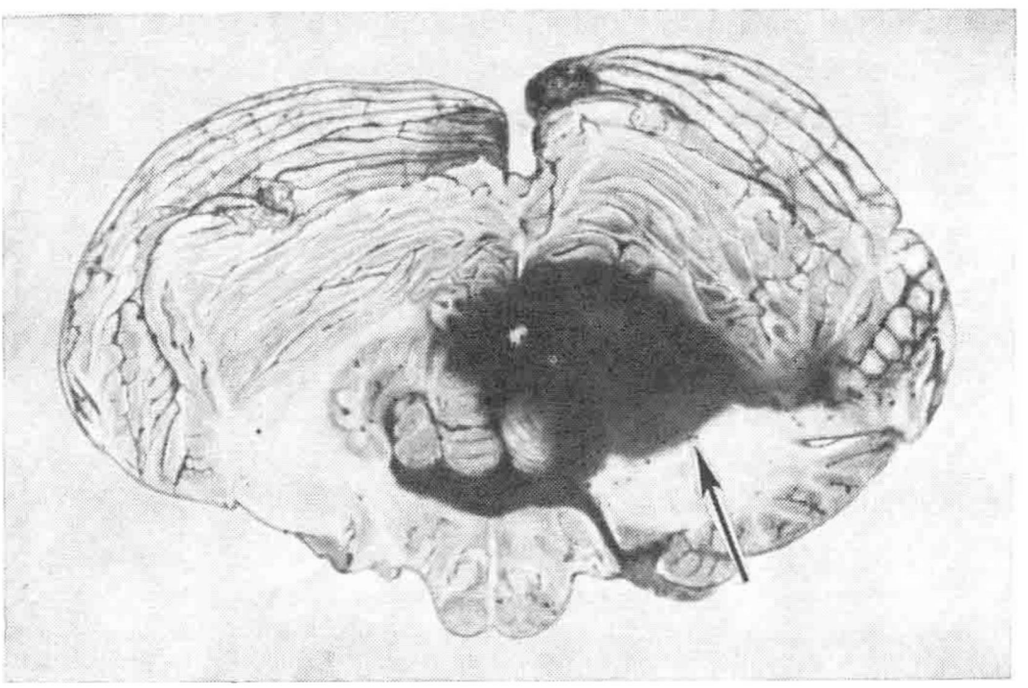


Fig. 26. A frontal section of the cerebellum and medulla oblongata with haemorrhage into the cerebellum (the haematoma is shown by the arrow).

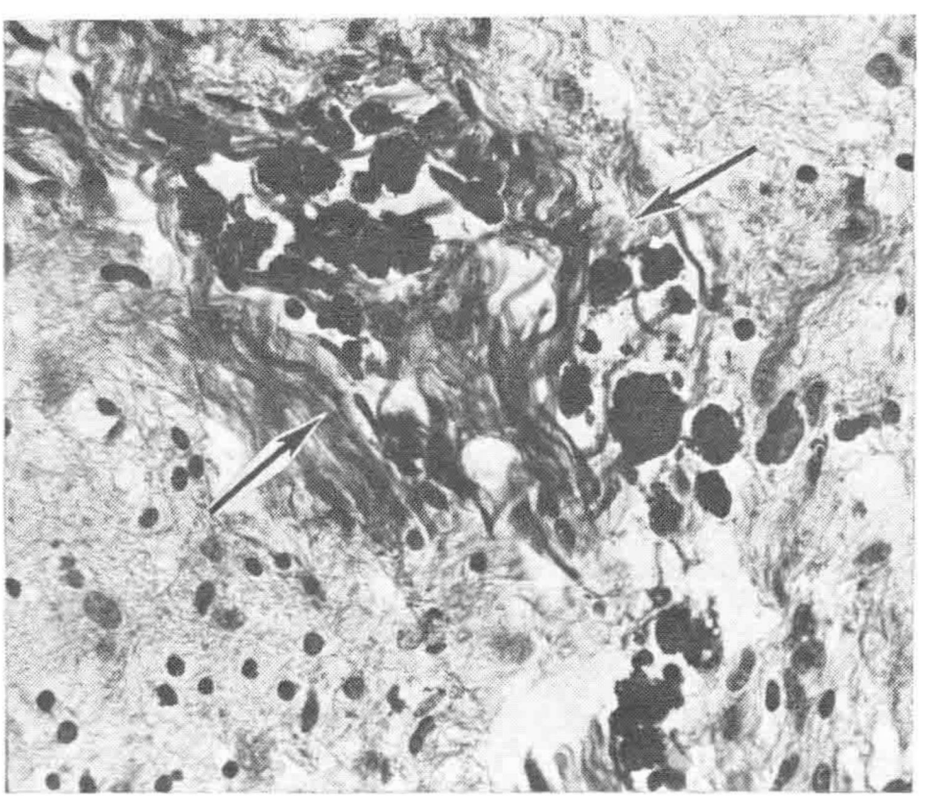


Fig. 27. A micropreparation of the brain tissue with a gliomesodermal cicatrix (shown by the arrows) with haemosiderin (of black colour) after a mild haemorrhage; stained according to Van Gieson; X200.

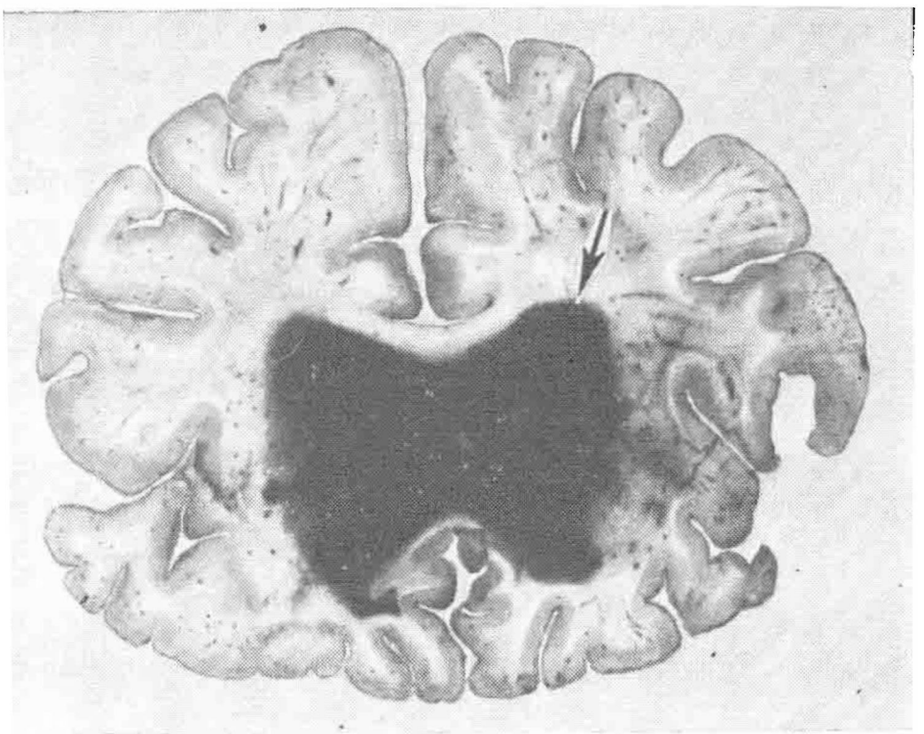


Fig. 28. A frontal section of the brain at the level of the anterior horns of the lateral ventricles with a rupture of an aneurysm of the anterior communicating artery; the ventricles are filled with blood (shown by the arrow).

whereas subarachnoid-parenchymatous haemorrhage is insignificant; that may give rise to an erroneous diagnosis of 'primary ventricular haemorrhage'.

Ischaemic stroke is followed by infarcts, i.e. focal necroses of the brain due to insufficient blood supply. The greater part of ischaemic strokes (60 per cent) is associated with atherosclerosis; the pathology of the extracranial portions of the carotid and vertebral arteries plays an important role in their development. A vessel may be completely obliterated due to thrombosis, thromboembolism or an atherosclerotic plaque. Thrombi are commonly formed near a plaque. Emboli may be composed of particles torn off from thrombi in the heart or from disintegrating atherosclerotic plaques in the aortic arch or carotids. An infarct may evolve without complete occlusion of a vessel, being caused by a kink or stenosis (extracerebral factors may essentially contribute to that — variation of arterial pressure, deterioration of cardiac activity, blood loss, etc.) and by the type of cerebrovascular insufficiency. Localization and size of infarcts may be very different. They are found most commonly in the basin of the middle cerebral artery (75 per cent), less often in the vertebrobasilar system (20 per cent). The size of infarcts depends on the level of occlusion. When arteries in the base of the brain or their branches are occluded, the infarct usually covers the whole area of vascularization of the 'cut out' vessel. In thrombosis of the carotid and vertebral arteries, infarct may not involve the

whole area, which depends on the possibility of redistribution of blood through the arteries of the base of the brain. In stenosis of the extracranial sections of the major arteries infarcts usually evolve in the cortex, in the area of fusion of their peripheral branches (*zones of contiguous blood supply*); there may be many small-sized infarcts in such a case (granular cortical atrophy).

Infarcts are distinguished by the degree of the haemorrhagic component. In *white* (*grey*) *infarcts*, the tissue is pale, flabby; they account for 85-90 per cent of all infarctions, and may occur in any brain area (Figs. 29 and 30). *Haemorrhagic infarctions* are seen as small red-coloured foci, they appear only in the grey substance, usually in the cortex (Fig. 31), not uncommonly due to thromboembolism. *Mixed infarcts* consist of white and red areas, the latter localizing mainly in the grey substance (Fig. 32).

The microscopic study of all kinds of infarcts in the initial period of stroke reveals some changes in the brain substance due to ischaemia: abnormality of nerve cells, mainly ischaemic (Fig. 33), and necrobiotic changes in the glia. The vessels are more resistant to ischaemia. Occasionally, there are some diapedetic haemorrhages from smaller vessels: in foci of grey infarcts they are rare and single, in foci of red infarcts and in some parts of mixed infarcts they are multiple and merge.

By the end of the first 24 hours, migration of leucocytes occurs, whose enzymes take part in the melting of the necrotized tissue (the beginning of 'softening'). In two or three days a process of 'tidying up' begins; granular fat globules (Fig. 34), mast astrocytes appear; further development of the focus proceeds with proliferation of fibrillar astrocytes, growth of new vessels and collagenic fibres; it ends with formation of a gliomesodermal scar in small foci or connective-tissue scars and multi-chamber cysts in extensive foci (Fig. 35).

There are cases when macroscopic examination does not reveal focus of complete necrosis or a scar, in spite of persistent neurological symptoms; a microscopic study in that case shows a focus of incomplete necrosis in the cortex (dead neurons and substituting astrogliosis).

Ischaemic stroke may be *complicated by a haemorrhage into the necrotized* ('*softened*') *tissue*; it differs from haemorrhagic infarct, because it may develop in various periods of the infarction process and anywhere within the focus. Such haemorrhages may be a sequel of a rise in arterial pressure and restoration of circulation through the necrobiotically changed vessels.

A cerebral oedema develops when there are extensive foci (in haemorrhages and infarcts); an increase in the size of the brain may be followed by dislocation of the brain stem and secondary haemorrhages here, most commonly in the pons (Fig. 36) or the tegmen

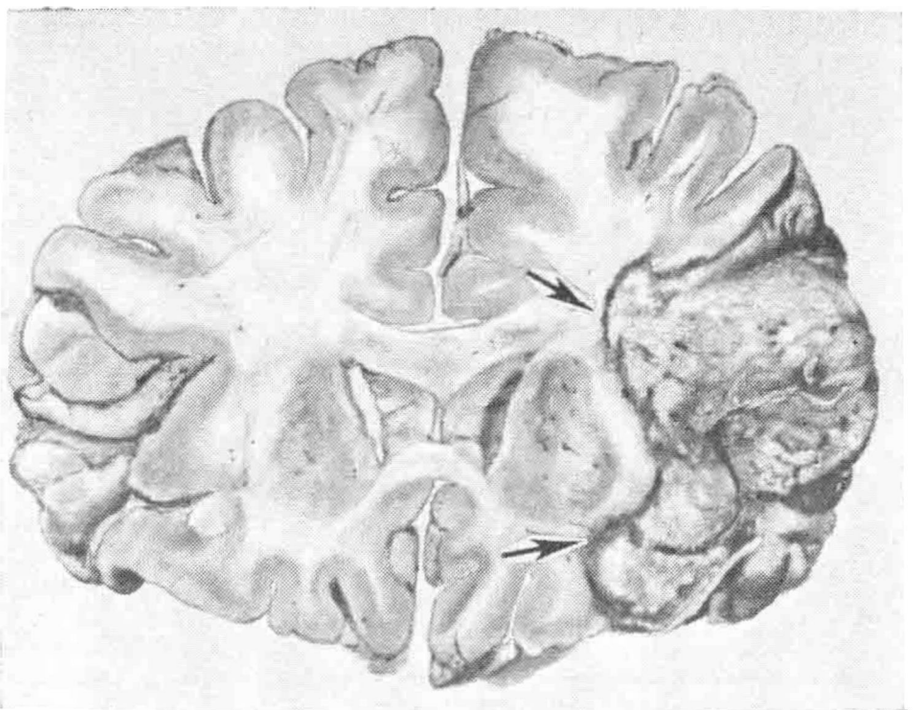


Fig. 29. A frontal section of the brain at the level of the anterior horns of the lateral ventricles: a white infarct (shown by the arrows) in the territory of the right middle cerebral artery.

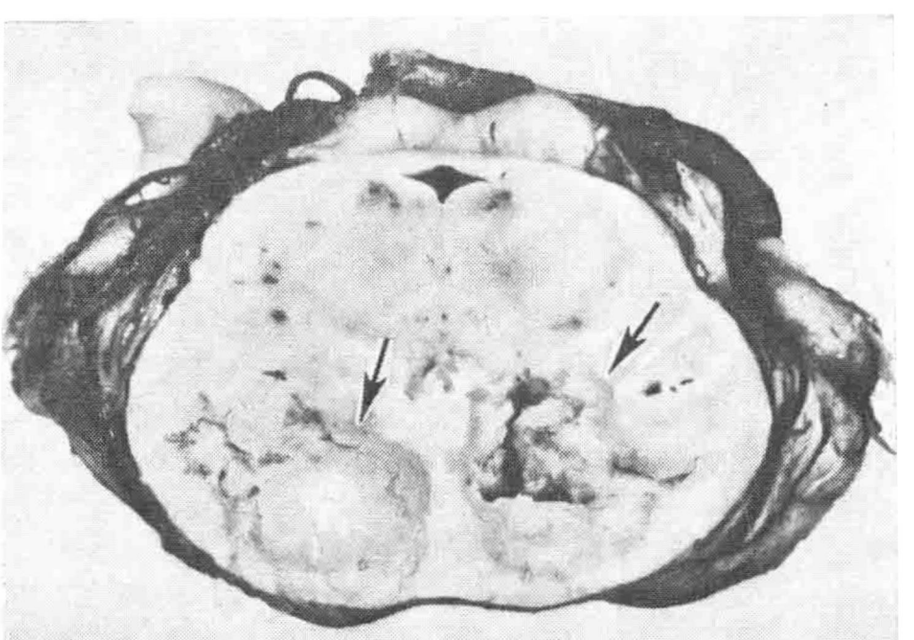


Fig. 30. A frontal section of the pons: a white infarct is shown by the arrows.

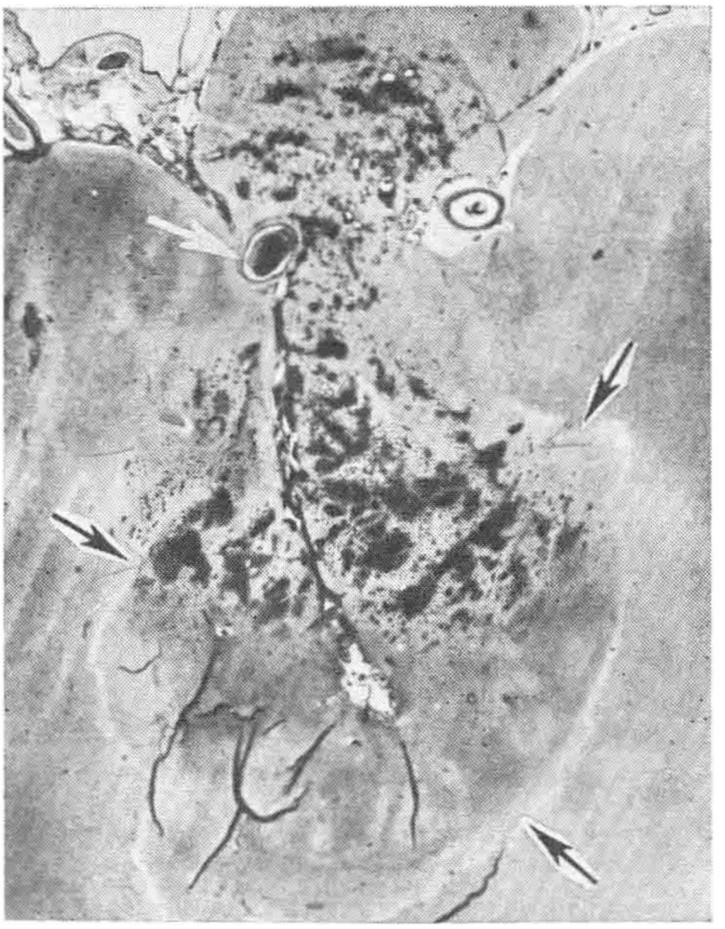


Fig. 31. A micropreparation of the brain: a small red infarct in the cortex (the black arrows show the boundary of the infarct); a thromboembolus in a superficial cerebral artery (shown by the white arrow); stained according to Nissl; X20.

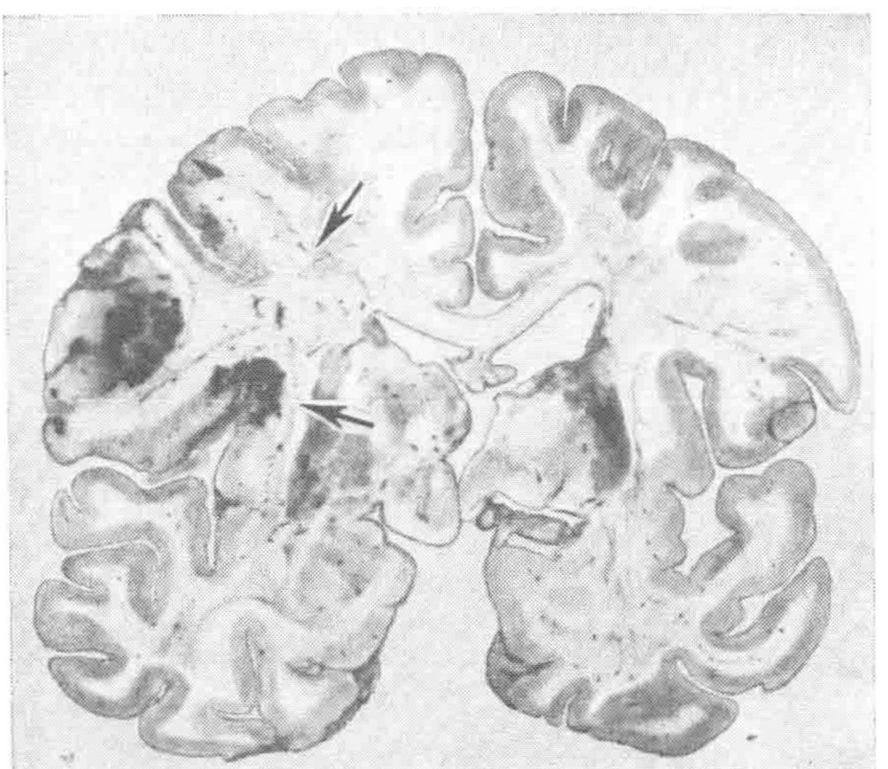


Fig. 32. A frontal section of the brain at the level of the thalami: a mixed infarct in the territory of the left middle cerebral artery (the arrows show the boundary of the infarct).

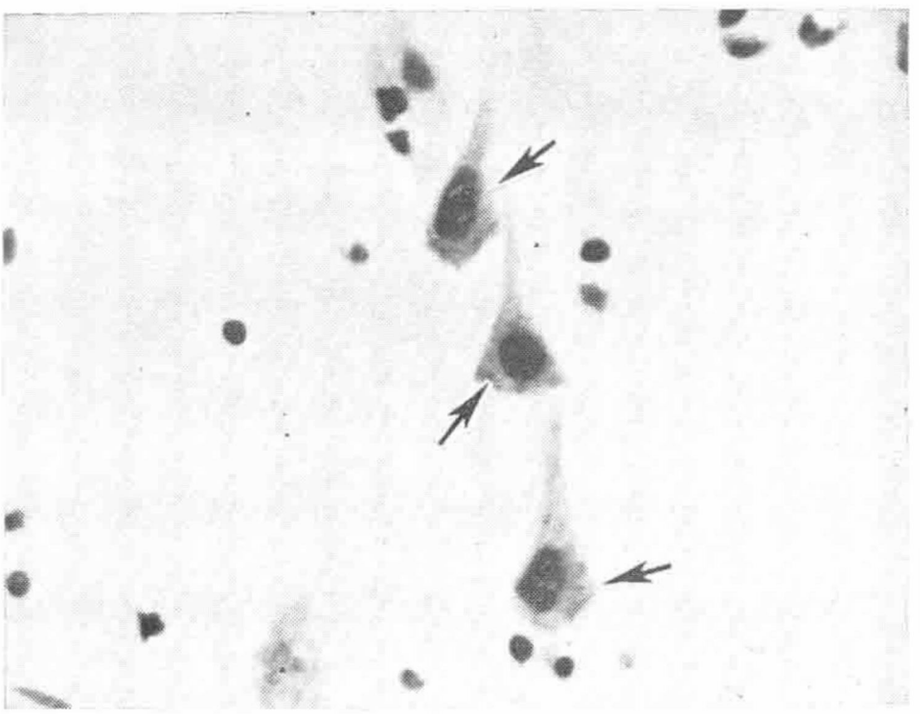


Fig. 33. A micropreparation of the brain: ischaemic changes in the nerve cells (shown by the arrows) of the brain cortex (change in the shape of the cell and its nucleus, disappearance of chromatin in the cytoplasm) in the first 24 hours of the stroke. Stained by Nissl; X600.

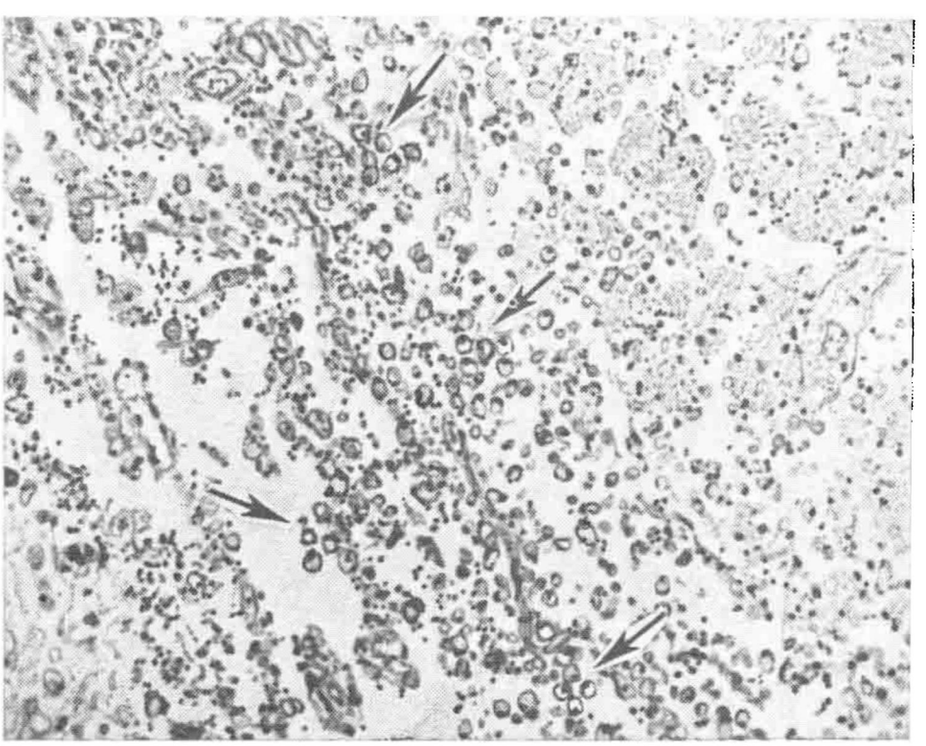


Fig. 34. A micropreparation of the brain: accumulation of granular globules (shown by the arrows) in the border zone of infarct. Stained by Van Gieson; X100.

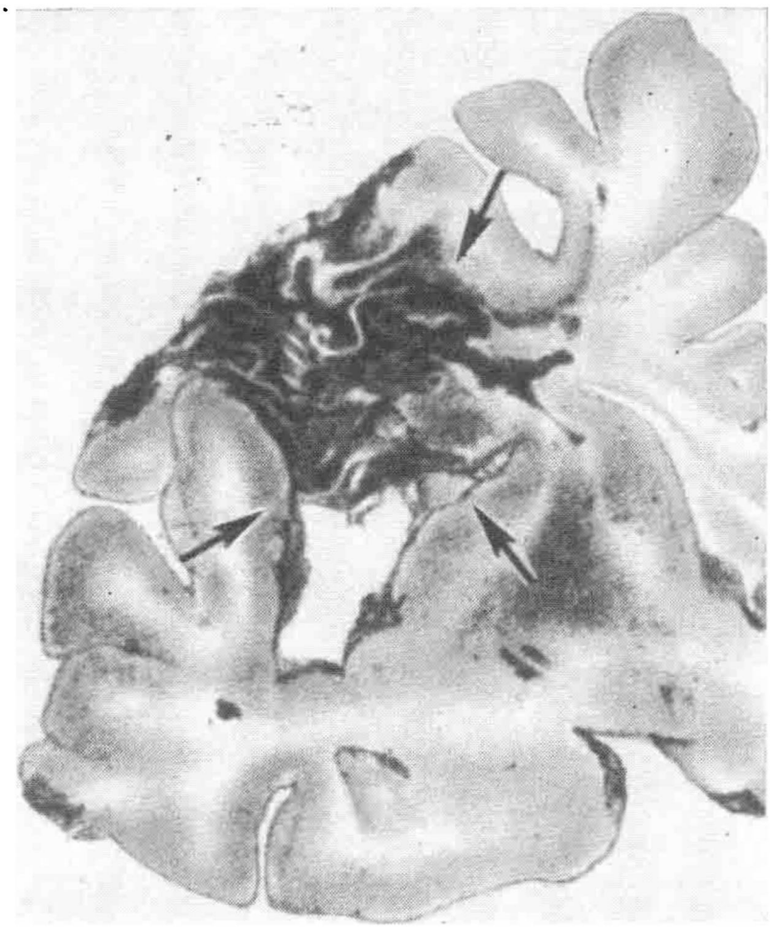


Fig. 35. A frontal section of the left hemisphere of the brain: a multilocular cyst (shown by the arrows) formed as a result of an infarct.

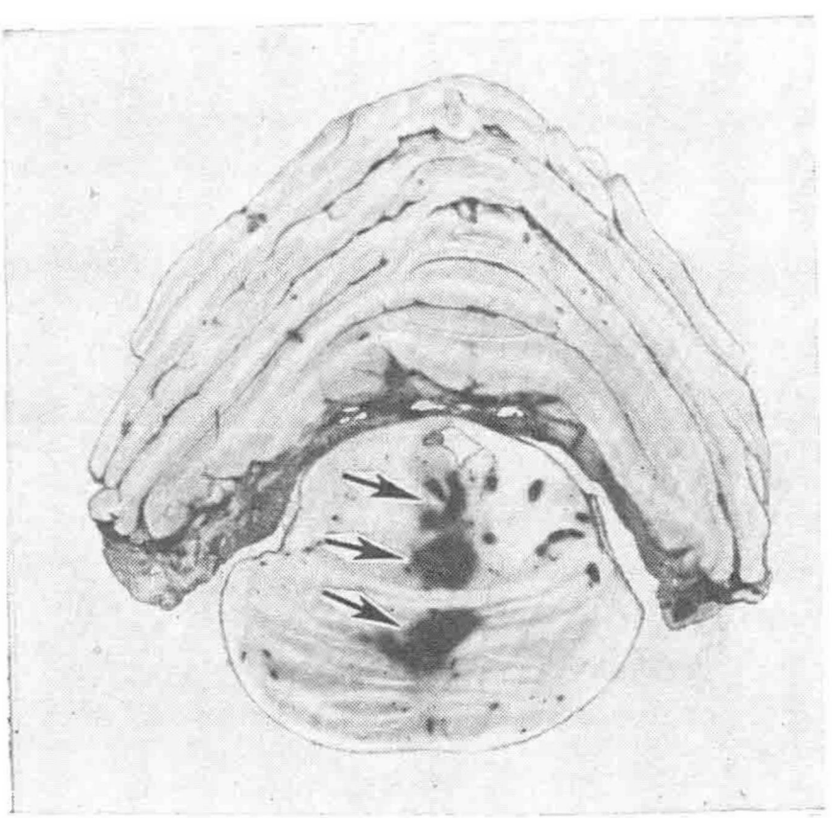


Fig. 36. A frontal section of the cerebellum and pons with secondary haemorrhages in the pons (shown by the arrows).

of the midbrain. Oedema with compression of the brain stem is the most frequent cause of the fatal outcome in strokes of both kinds. Death may also occur after a haemorrhage when there is a voluminous focus with blood breaching into the system of the brain ventricles. Foci in the brain stem, destroying vital centres, should be considered an immediate cause of death. Pneumonia and cardiac failure favour mortality in cases of cerebral infarction.

4.7. Changes in the Ultrastructure of Neurons and Interneuronal Junctions

Analysis of structural changes in neurons and their interneuronal junctions (synaptic junctions) is very important in understanding the mechanisms of various forms of functional disorders of cerebral circulation. The reason is that loss of a function is due to irreversible damage to neurons, whereas the reversibility of changes in the neurons is closely linked with the degree of preservation of their ultrastructure. On the other hand, reorganization of intercentral and synaptic junctions detected by the electron microscope is largely responsible for the compensatory and restorative processes. In the long run, the severity of the patient's condition is determined by the degree of the reactive and destructive changes in the neurons.

Wide use of electron-microscopic methods in pathohistological studies makes it possible to reveal the dynamics of the damaged cell organelles, the interconnection between the changes in separate organelles in the overall picture of cell damage, and in certain cases to study the pathology of the nerve cell on the macromolecular level. Electron microscopy has added another dimension to the neurohistological research into the brain, providing a new qualitative level in the study of the neuron.

There are two principal functions of the nerve cell: (1) the specific function of processing the arriving information and transmission of the primary impulse, and (2) the biospecific function which is performed to maintain the cell's life. This is reflected in the ultrastructure of the nerve cell in which organelles providing energy metabolism, protein synthesis, etc. are subject to performance of the specific function of the neurons. Transmission of information from one nerve cell to another, association of the cells into systems and combinations of various complexity determine existence of specific structures in the nerve cell—axons, dendrites, and synapses. Oxidation metabolism is performed mainly by mitochondria; an active part in the protein synthesis is played by the nucleus, nucleolus, granular reticulum and agranular reticulum, polysomes and ribosomes.

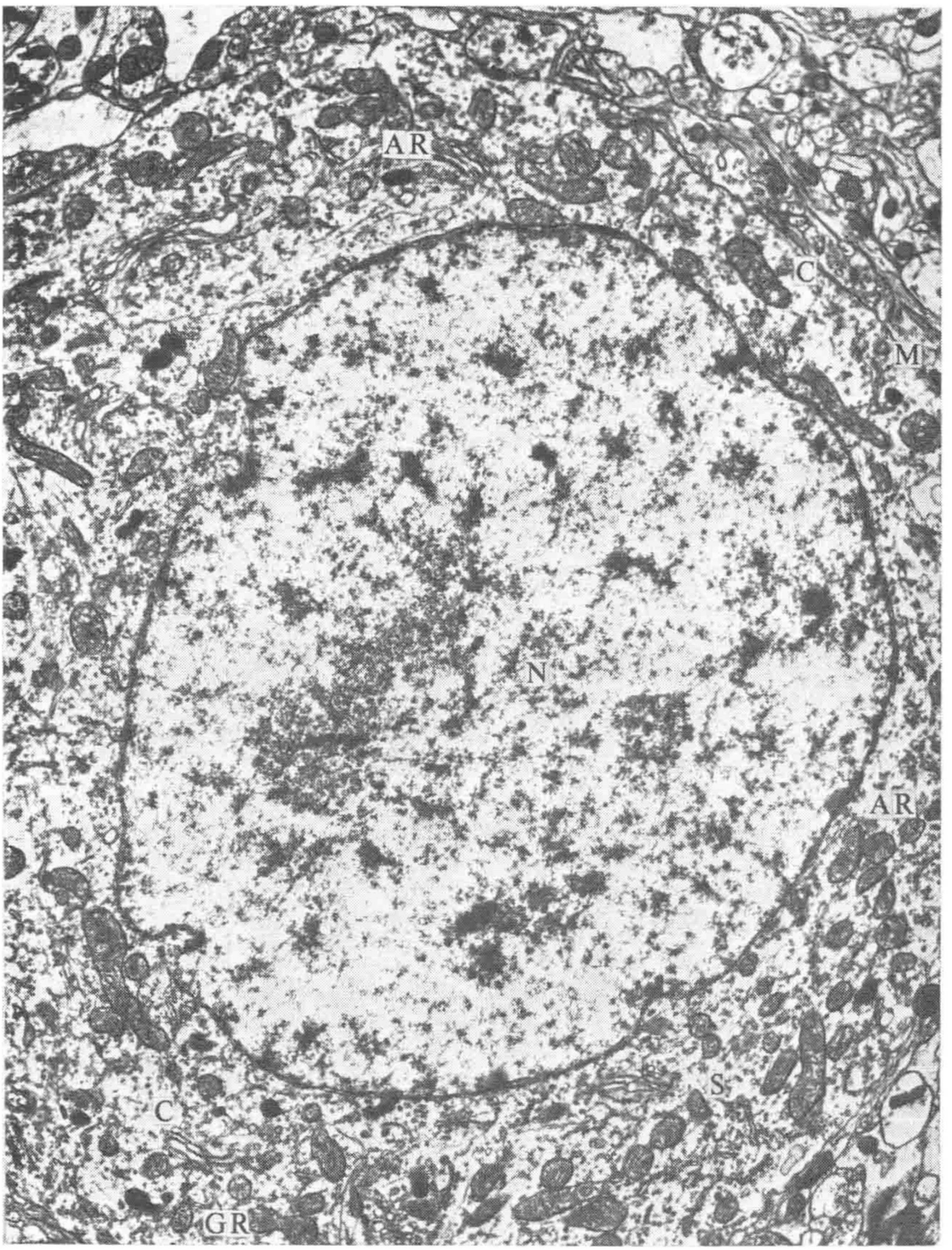


Fig. 37. Ultrastructure of the nerve cell under normal conditions; X16 000.

A typical example of the ultrastructure of a normal **nerve cell** is shown in Fig. 37. The body of the cell, seen in electronographs, is round or oval; the centre is occupied by the electron-transparent nucleus, containing the nucleolus and a moderate number of chromatin lumps.

The cytoplasm of the nerve cells contains elements of granular and agranular reticulum, polysomes, ribosomes, mitochondria, lysosomes, multivesicular bodies and other organelles.

The granular reticulum is a system of tubules with ribosomes attached to them. Accumulation of such tubules forms a lump of tigroid. Usually, numerous polysomes are unevenly distributed in the cytoplasm. The agranular reticulum is a tight mass of cisterns without ribosomes attached to them but with many vesicles around their accumulations. The mitochondria are rod-shaped or spherical bodies enclosed into internal and external membranes. The internal membrane has numerous cristae.

An important role in the cell metabolism is played by lysosomes which are round or irregular osmiophilic membrane-enclosed formations. Not uncommonly the lysosomes are of uneven electron density, being filled as it were with fine granular material; they contain vacuoles and focal lucidifications of various size and electron density. The cytoplasm of the nerve cell body is sometimes filled with a small number of tubules and neurofilaments, and with a few multivesicular bodies, osmiophilic inclusions and some other ultrastructures.

Pathocytology of the neuron. Disturbances of cerebral circulation cause damage to the brain as a whole; a focal lesion, localized in some brain area, is far from the total of the damage, which is a sum of the reactive and destructive processes in the neurons of the various brain formations. The pathomorphological changes in a stroke are seen as gross pathology in the nerve cells proximal to the focus of haemorrhage or ischaemia and cell destruction of various severity, which is found far from the focus, sometimes in the contralateral hemisphere, or in the brain stem.

Electron microscopy of the brain shows first of all that a stroke, be it haemorrhagic or ischaemic, and irrespective of its localization, causes sufficiently marked pathocytological changes in the nerve cells, both proximal and distal to the focus of affection, which are evidently due to haemodynamic disturbances, cerebral hypoxia, oedema, disorders of acid-base equilibrium, etc.

Changes in the nerve cells in cerebral stroke are characterized by marked polymorphism, which is seen under the light microscope and is still more pronounced as seen under the electron microscope. These changes include chromatolysis of various degree, hyperchromatosis, 'ischaemic disease' of the cells both with and with-

out incrustations, homogenization of the cytoplasm, appearance of 'shadow cells' and, finally, focal disappearance of the cells.

The electron microscopic study reveals the pathology of the most part of cell organelles. Abnormality of mitochondria is most pronounced in which there are decreased number of cristae, focal or general swelling, disintegration of the internal membrane, and finally their fragmentation. The swelling of the mitochondria in the first phase indicates the presence of the reactive and compensatory processes in the cell, while degeneration of the membranes and fragmentation of mitochondria spell gross disorder of the oxidation metabolism. Essential damage is found in the granular reticulum, whose tubules and cisterns swell or fragmentate, thus lowering the number of intracellular membranes. Reactive changes are seen at the same time in the agranular reticulum; the number of element accumulations there may be even somewhat increased. Ultrastructural disorders in the organelles of the nerve cell cytoplasm, associated with protein-synthesizing function, are combined with noticeable changes in the nucleus and nucleolus.

Disorders in the protein-synthesizing structures are pronounced differently and under the electron microscope the changes in the lipoproteins of cyto- and karyoplasm may be seen either as lucidification or as an increase of electron density of cyto- and karyoplasm. The former is mainly the case of chromatolysis and acute swelling. The concept of 'high electron density of cyto- and karyoplasm' includes hyperchromatosis, pyknosis, sclerosis, and ischaemic, homogenizing, severe disease of the cells, etc.

The most characteristic pathology of the nerve cells is seen in neurons with 'ischaemic disease' (Fig. 38). These cells are characterized primarily by osmiophilic cytoplasm and karyoplasm. Owing to higher electron density the soma of neurons is clearly seen on a background of cut in various directions axons, dendrites and processes of glial cells. Such cells are called 'dark' neurons.

Recently, most of the researchers began to consider neurons with greater cyto- and karyoplasmic osmiophilia to be a form of damage typical of cerebral hypoxia or ischaemia. There is also an opinion that the 'dark' neurons are no more than artifacts or an effect of a postmortem trauma.

The 'dark' neurons are characterized by increased osmiophilia combined with severe damage to their structure. The osmiophilic nucleus acquires an irregular form, it often stretches and becomes rod-shaped, shrivelled, with a corrugated contour, less often it is polygonal and multilobed. The perinuclear space is expanded, sometimes there are large cavities between the nuclear membranes. The electron density of the cytoplasm is sharply increased. This is concomitant with disappearance of accumulations of granular reticulum, diminished number of the elements of the granular retic-

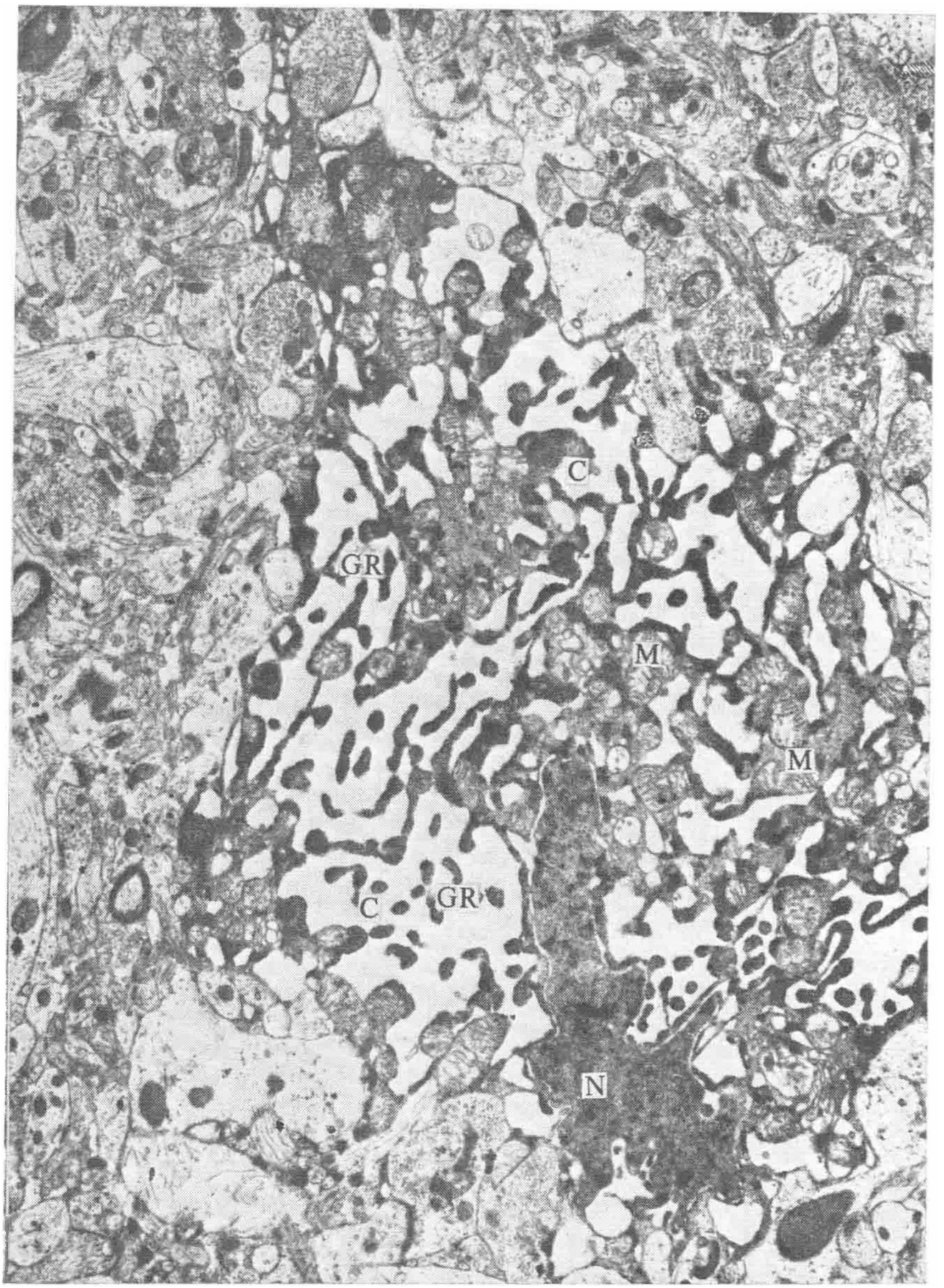


Fig. 38. Ischaemic disease of the nerve cell. A case of a fatal stroke; X15 000.

ulum and polysomes. Mitochondria swell, there are much less cristae in them, and they are transformed into bright and vacuole-like formations. The transformation of mitochondria comes along with appearance of a great number of vacuoles of various size: multiple small vacuoles may form due to hydropic changes in the lipoprotein complexes of the cytoplasm; large vacuoles may form due to the gross change in the mitochondria, cisterns of the agranular or granular reticulum, etc. That kind of the nerve cell transformation occurs in acutely developing ischaemia or hypoxia, and it speaks of a relatively short period of the process.

The ultrastructure of the osmiophilic neurons somewhat differs in patients with prolonged hypertensive disease, pronounced atherosclerosis, and when they have long been in a severe, unconscious state before death. Mitochondria seem to be more preserved, apparently due to formation of new small, crista-rich organelles. The vacuoles and distended cisterns of the endoplasmic reticulum fuse into large cavities, which 'compress', as it were, the cytoplasm between them. In this case the cytoplasm resembles lace pattern, sometimes it seems clarified at low magnification due to a great number of large lucid cavities of irregular shape, among which the osmiophilic cytoplasm appears in narrow strips and islets. The periphery of the cell cytoplasm appears to be occupied with sites of higher electron density. The contour of the nerve cell is irregular, some bits of the cytoplasm are submerged into the processes of the astrocytes. The astrocyte processes themselves are partly submerged into the cytoplasm. Irregular contours of the cells due to submersion of the astrocytes and separation of its parts form the patterns described as 'incrustations' in the findings of the studies under the light microscope, which is the evidence of the initial degeneration of the cell.

Destruction of intracellular membranes and damage to the ones around the cell is a characteristic change in the ultrastructure. The cells are no more intact, their legibility is reduced, they are unevenly stained; not uncommonly numerous small-sized granules are seen instead of a smooth clear-cut contour. All that seems to stem from the change in the permeability of the cell membranes, which is an essential point in the water and electrolyte equilibrium in the cell. Rapid development of that kind causes acute swelling and intracellular oedema, vacuolization, and other abnormalities. Oligodendrocytes and astrocytes that are often contiguous to the neuron submerge, as it were, into the damaged nerve cell. The membranes, separating the nerve and the glial cell, are partially destroyed, and it is not feasible now to see them apart. Destruction of these membranes is a clear sign of the starting neuronophagia, the final stages of which are seen under the light microscope as submersion of the glial cell into the neuron.

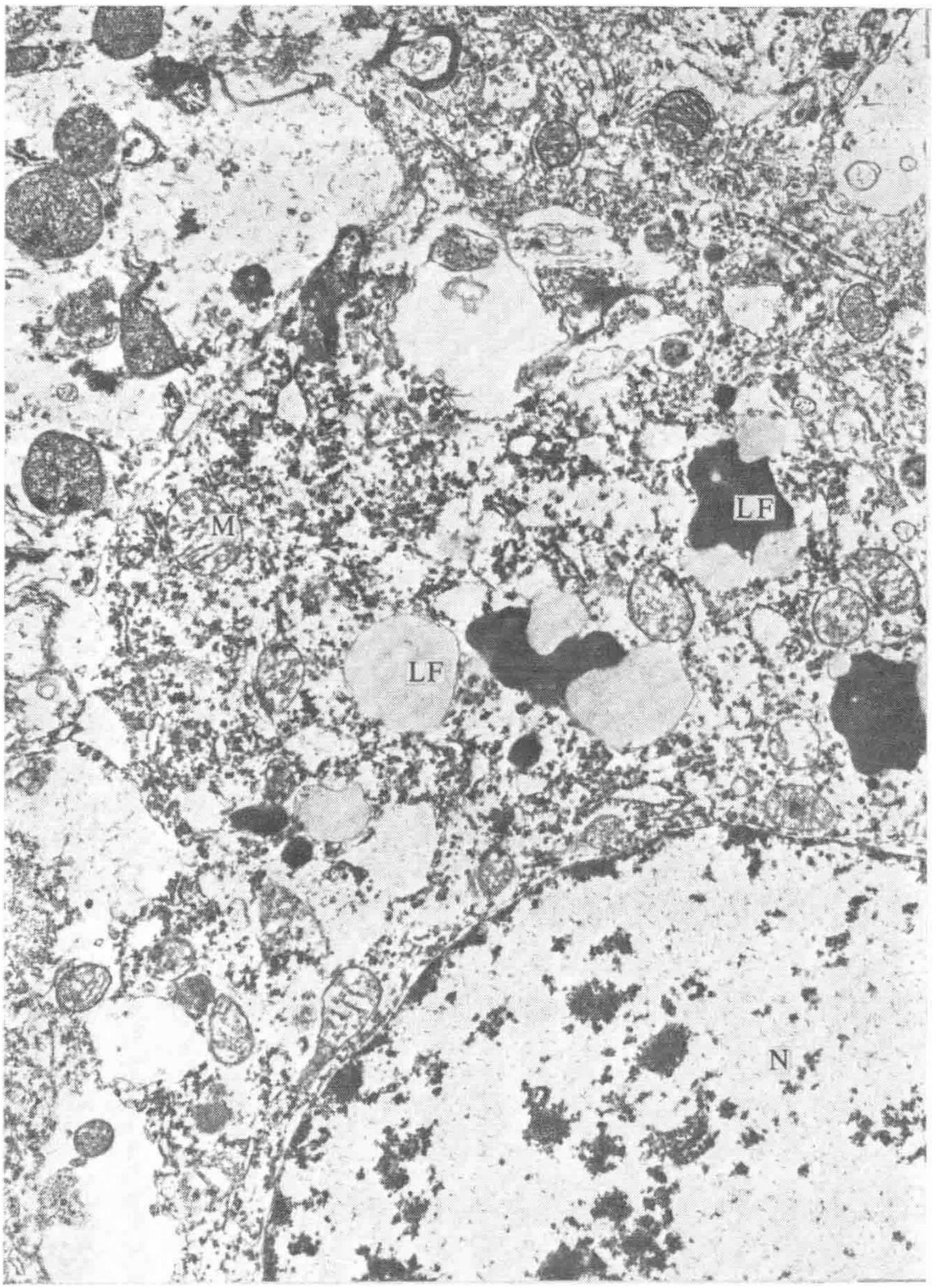


Fig. 39. Accumulation of lipofuscin in the nerve cell. A case of a fatal stroke; X40 000.

The changes which are very characteristic for the postmortem picture of the cortex neurons of a patient who has died of a stroke are shown in Fig. 39. The most essential in this picture is a sharp rise in the number of lysosomes, lipid inclusions, and lipofuscin granules, which are not always easy to distinguish applying only standard electron-microscopic techniques, without histochemical tests. Lipid globules and lipofuscin granules are distinctly seen against bright electron-transparent cytoplasm as round or irregular inclusions of various osmiophilic degree and electron density. Such cells have a lucid nucleus, otherwise normal except for improper distribution of chromatin. The cytoplasm does not contain formed accumulations of the elements of the granular reticulum, the number of polyribosomes is reduced, and focal destruction may be sometimes revealed. Mitochondria are less changed, cristae and membranes of the most of them are intact, though some swelled organelles without cristae can be seen.

The rise in the number of the lipofuscin granules, lysosomes, and lipid globules is characteristic of the neurons. They are more commonly revealed in the neurons changed by the 'lucid' type, i.e. in the cells where the abnormal changes are not accompanied with a rise in the osmiophilic quality of the cyto- and karyoplasm (see Fig. 39). But the lipofuscin and the lipid granules may also be found in the neurons with clearly increased electron density of both nucleus and cytoplasm. That is shown in Fig. 40, where lipofuscin granules are seen as large accumulations. Now elements of the granular reticulum do not form the lumps of tigroid, and the number of tubules of the granular reticulum is sharply reduced. The cell contains but a few groups of cisterns of the agranular reticulum.

Commonly, various stages of chromatolysis may be found in the nerve cells. In acute fatal cases, chromatolysis is more often peripheral or segmentary. If the patient dies several days after the stroke or there was a prolonged agony, it is either central or focal or total.

A neuron with central chromatolysis is shown in Fig. 41. Electron microscopic chromatolysis in the neurons at the early stages of the process is displayed by disappearance of the formed accumulations of the granular reticulum, a decrease in the number of polysomes, occurrence of swelled mitochondria, some rise in the number of lysosomes, and by an uneven contour of the nucleus. Not uncommonly chromatolysis goes along with hydropic changes, which is revealed in formation of vacuoles of various shape and size in the cytoplasm of the neuron. Later lucid foci devoid of organelles, destruction areas, membrane inclusions and myelin-like bodies appear in the cytoplasm. Such neurons show uneven contour of the cell membrane.

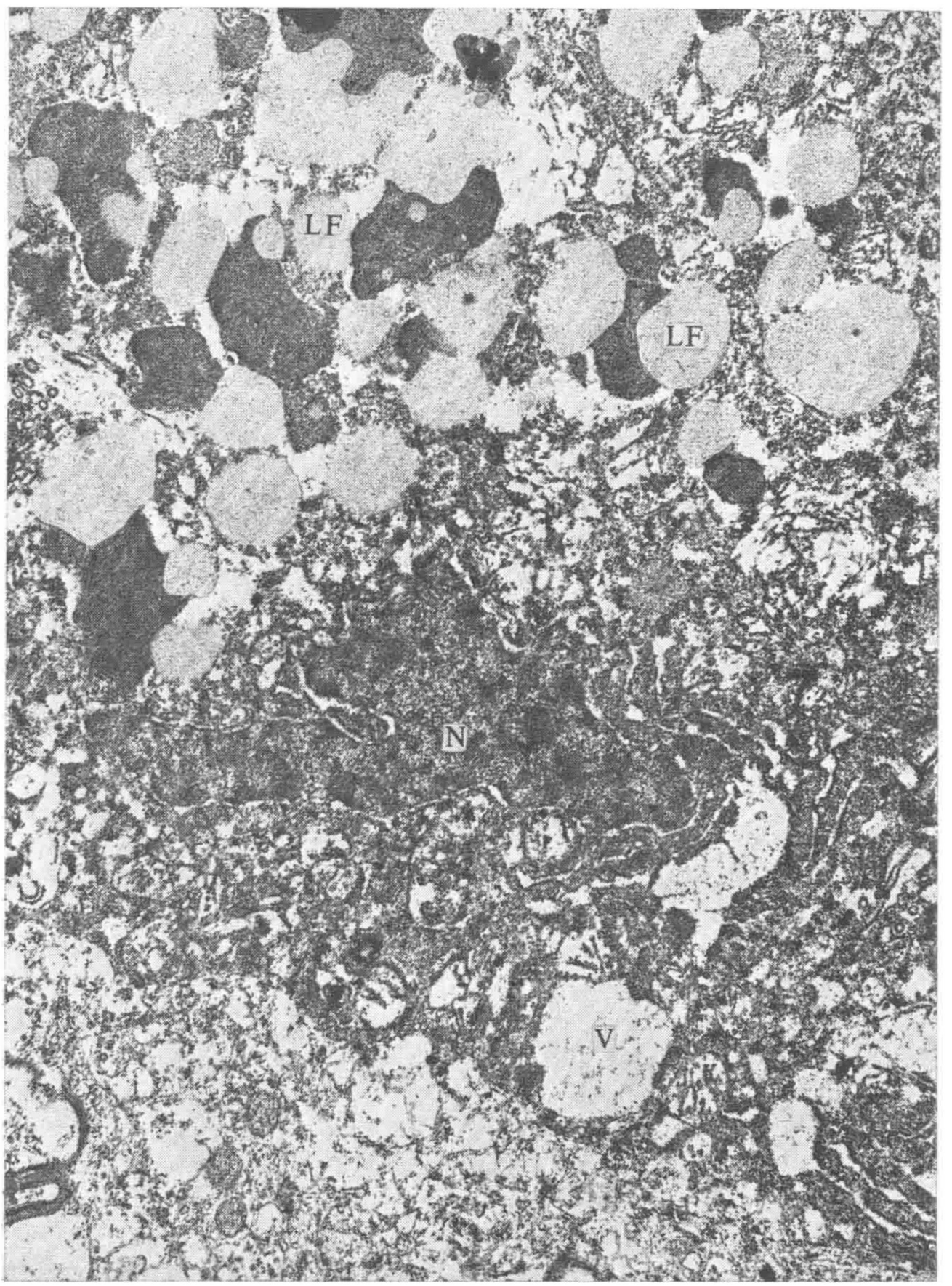


Fig. 40. Accumulation of lipofuscin in the nerve cell with elevated osmiophilia of the nucleus and cytoplasm. A case of a fatal stroke; X40 000.

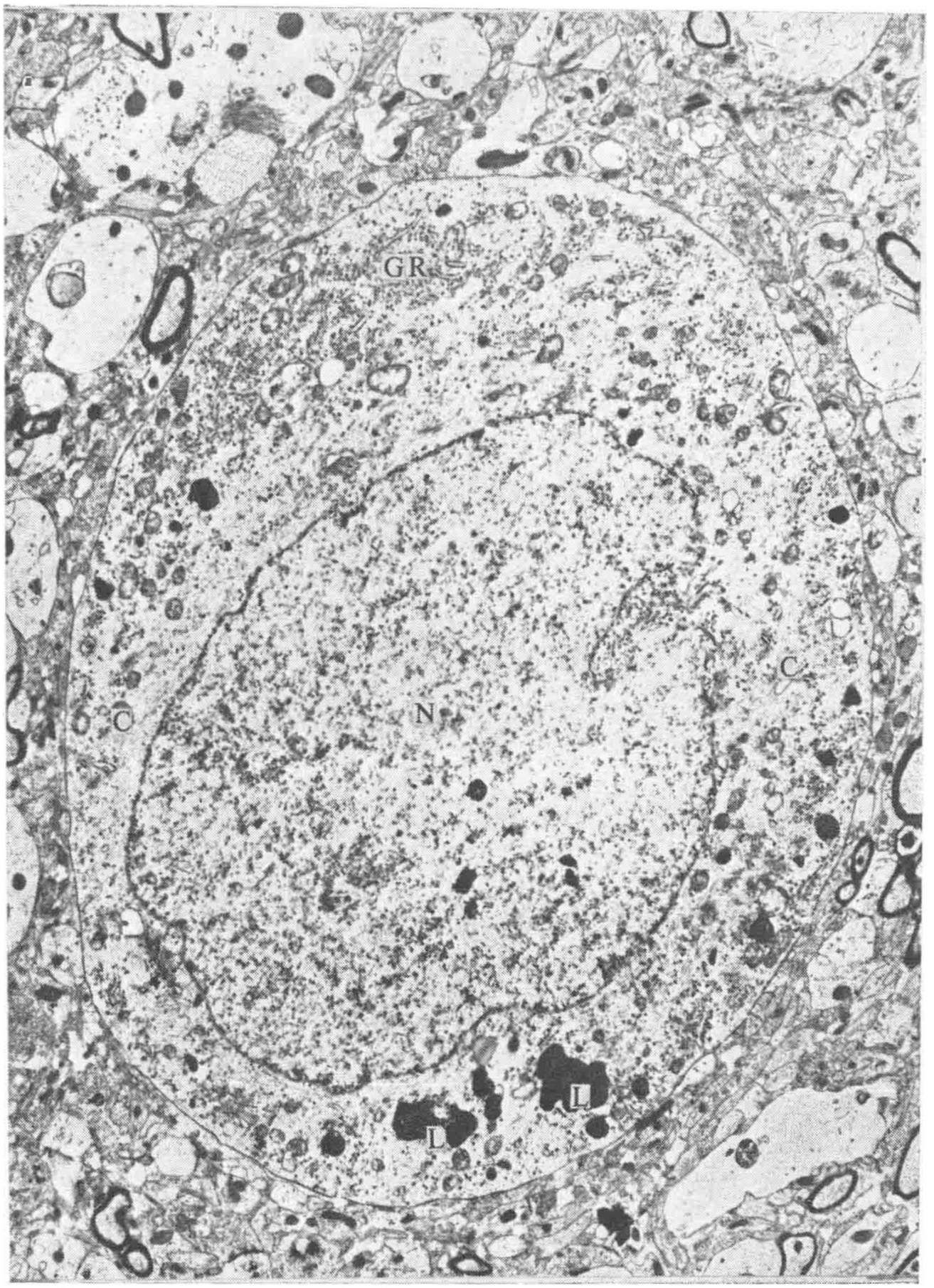


Fig. 41. Chromatolysis of the nerve cell. A case of a fatal stroke; X12 000.

The extent to which the findings of the electron microscopy might be correlated with the clinical picture is a difficult question which requires further study. Now it seems feasible only to consider some points which might be useful for elaboration of purposeful therapy.

Pathomorphological changes in most of the mitochondria of the neurons, which indicates an essential disorder of the oxidation metabolism of the cell, are observed in patients without long-term hypertensive disease in whom the process developed acutely and comparatively rapidly (between several hours and several days) and had a fatal outcome.

The changes in the ultrastructure of the mitochondria are not so well pronounced in patients with a gradual development of the morbid state, a long-term hypertensive disease and atherosclerosis, and records of disturbances of cerebral circulation in their case history. Disorders of the cell structures involved in the protein synthesis (the nucleus, nucleolus, granular and agranular reticulum, ribosomes, polysomes, etc.) are more essential in such patients.

Neurons with 'ischaemic disease' prevail in the patients with an intense process, while the patients with chronic and gradual development of the morbid condition have various forms of chromatolytic reaction of the neurons, attended with pronounced lysosomal reaction, hydropic changes in the form of numerous vacuoles, focal destruction of the cytoplasm, and considerably poorer preservation of the cell membranes.

Considering ultrastructure of the neurons of cerebral formations distal from the focus of lesion, e.g. in the cortex of the contralateral hemisphere, a greater degree of pathomorphological changes is observed in patients dying relatively young as compared to that of patients dying at 75-80. The ultrastructure of glial cells, primarily astrocytes, is seen to be more distinctly transformed in elderly patients.

Trophic disorders of the nerve cells bear on the dynamics of the ageing process of the glial cells considerably. There is an impression that the trophicity of the nerve cells in the elderly persons is already impaired due to the change in the neuroglial interrelationship, and development of the pathological process in the neurons may be triggered by disturbances of cerebral circulation of less severity than in young persons.

Pathocytology of the glial cells. In view of the present-day concept of microcirculation, the nerve cell, the glial cell, and the capillary should be considered as an inalienable unity. The glial cells and the patterns of the membrane transport play an important role in cell pathology. Both reactive and destructive changes in the glial cells are seen in vascular disorders under the light microscope. Electron microscopy has essentially contributed to understanding

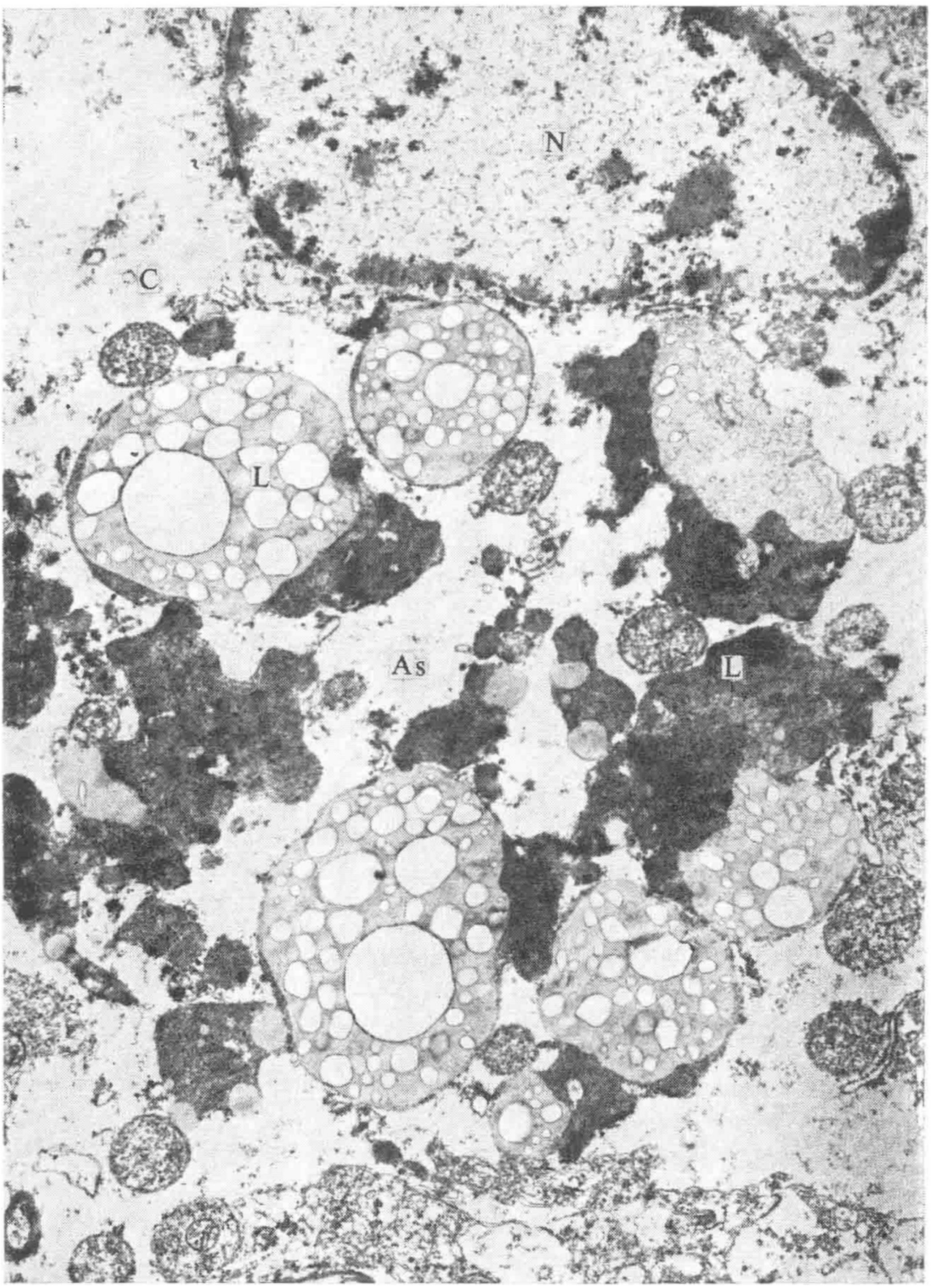


Fig. 42. Accumulation of lysosomes and lipofuscin in an astrocyte. A case of a fatal stroke; X40 000.

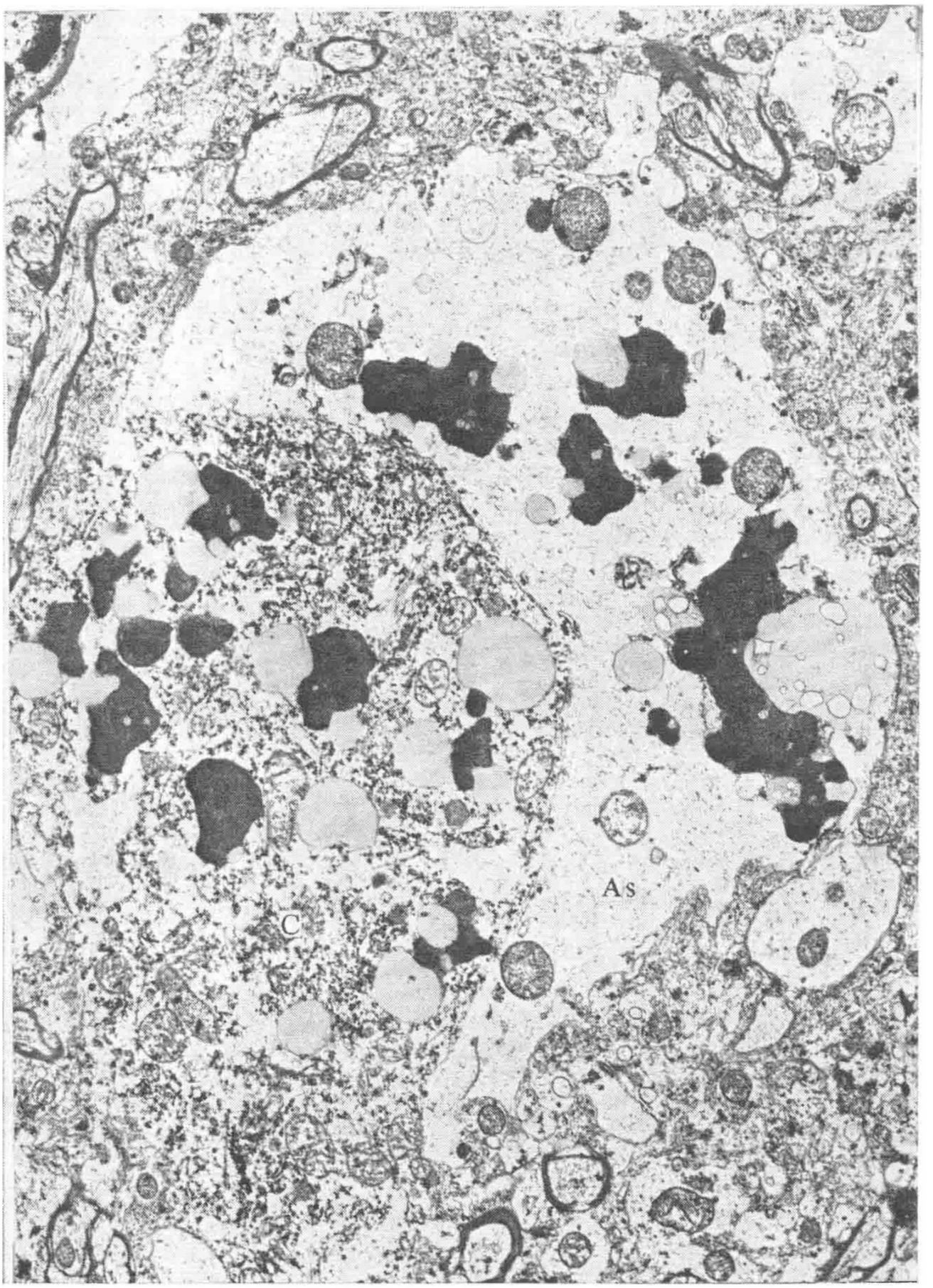


Fig. 43. Similar to Fig. 42 change in a nerve cell and in a contiguous process of an astrocyte (accumulation of lysosomes and lipofuscin); X25 000.

that, showing the change in the organelles of the glial cells due to their metabolic disorders. Special attention has to be paid to the astrocyte reaction. It may be displayed, on the one hand, by an increase of the number and size of the astrocyte processes, which is a morphological expression of cerebral oedema, and on the other hand, by the appearance of a greater number of lysosomes and osmiophilic inclusions of various size (Fig. 42), while the astrocytes in health are characterized by lucid, electron-transparent cytoplasm and a small number of organelles, more often the cytoplasm seems to be as it were 'empty'. A typical symptom of astrocyte lesion in patients who have died of stroke are accumulations of lysosomes and osmiophilic inclusions. Not uncommonly the appearance of lysosomes in the astrocyte processes correlates with accumulation of lysosomes and lipofuscin granules in the neurons contiguous to these processes of the glial cells (Fig. 43). This indicates that the trend of the destructive changes in both neurons and astrocytes is similar. An increased area of astrocyte-neuron contact, shown in Fig. 40, gives an evidence of more intense metabolism between them. At the same time, such a gross change in the glial cell results in an essential impairment of the transport through it—both from the capillary into the neuron and in the opposite direction.

Ultrastructure of the capillaries. The pathological changes in the nerve cells distal from the focus of lesion are considerably determined by the disorders of haemodynamics due to development of stroke. There is a noticeable damage to the ultrastructure of the capillaries which causes changes in their permeability and may determine impairment of the cell structure and function which is growing after the onset of stroke.

The so-called 'no-reflow' phenomenon following ischaemia is widely discussed now. The writers, who have first described the phenomenon, considered that the postischaemic no-reflow in the capillaries is due to swelling of the processes of the pericapillary astrocytes, as if compressing the vessel. Our data do not allow us to agree with that assumption. The pericapillary oedema, regularly developing in patients with disturbances of cerebral circulation, in most of the cases is not associated with narrowing of the capillary lumen (Fig. 44). It should be noted, however, that there are signs of essential damage to the ultrastructure of the endothelial cells, where the nucleus is transformed, the number of organelles decreases, most of the mitochondria swell and fragmentize, the number of the pinocytotic vesicles increases, and vacuoles appear. The damage to the basal membrane is especially clear: its thickness becomes uneven, and vacuoles and foci of destruction appear within it (Fig. 45). There is an essential deterioration in the pericytes as well (Fig. 46). All that indicates an important change in all the basic structures of cerebral capillaries, which naturally leads to trophic disor-

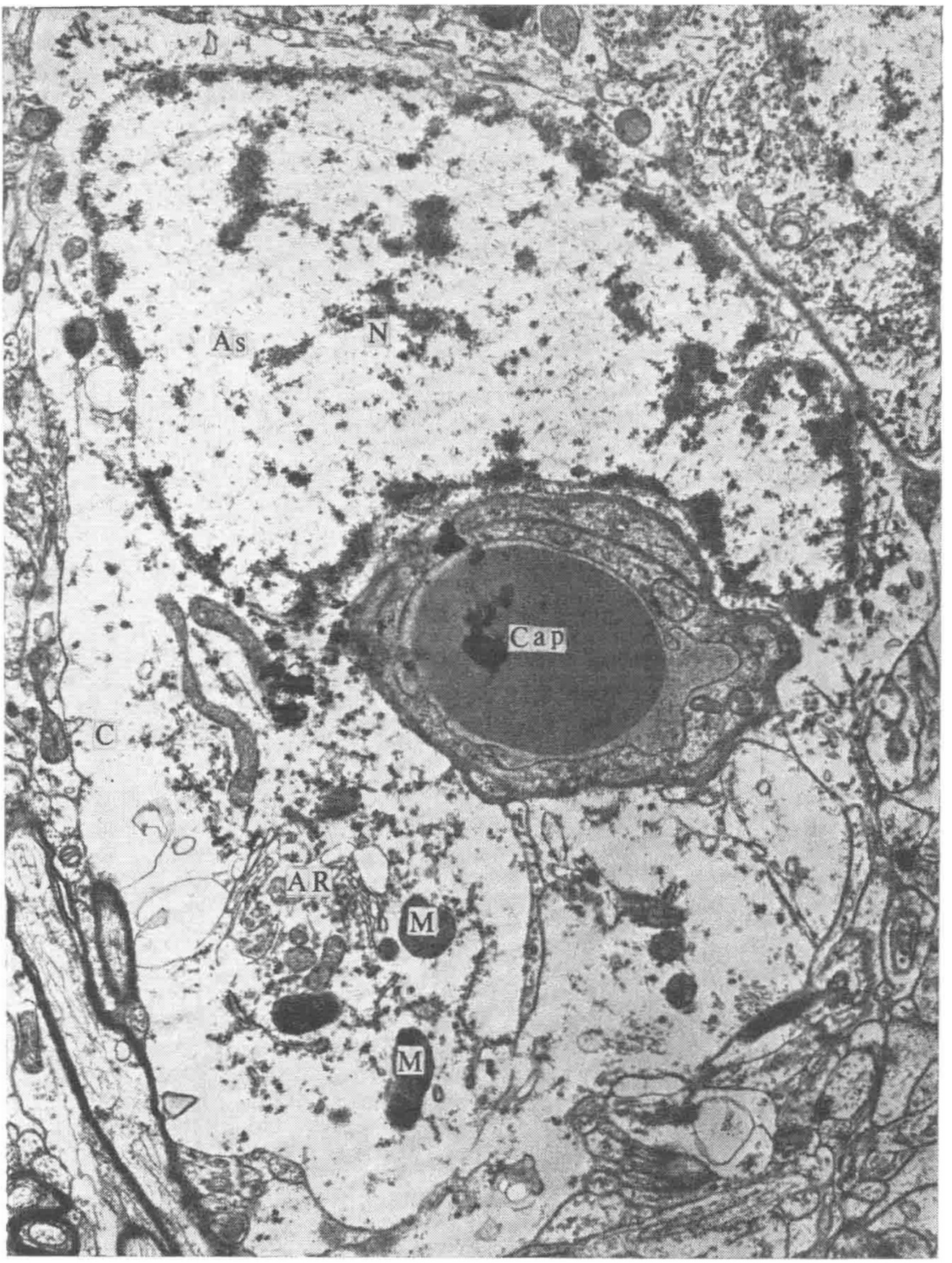


Fig. 44. Accumulation of astrocytes and swelling of their processes constituting a 'pericapillary oedema'. A case of a fatal stroke; X16 000.

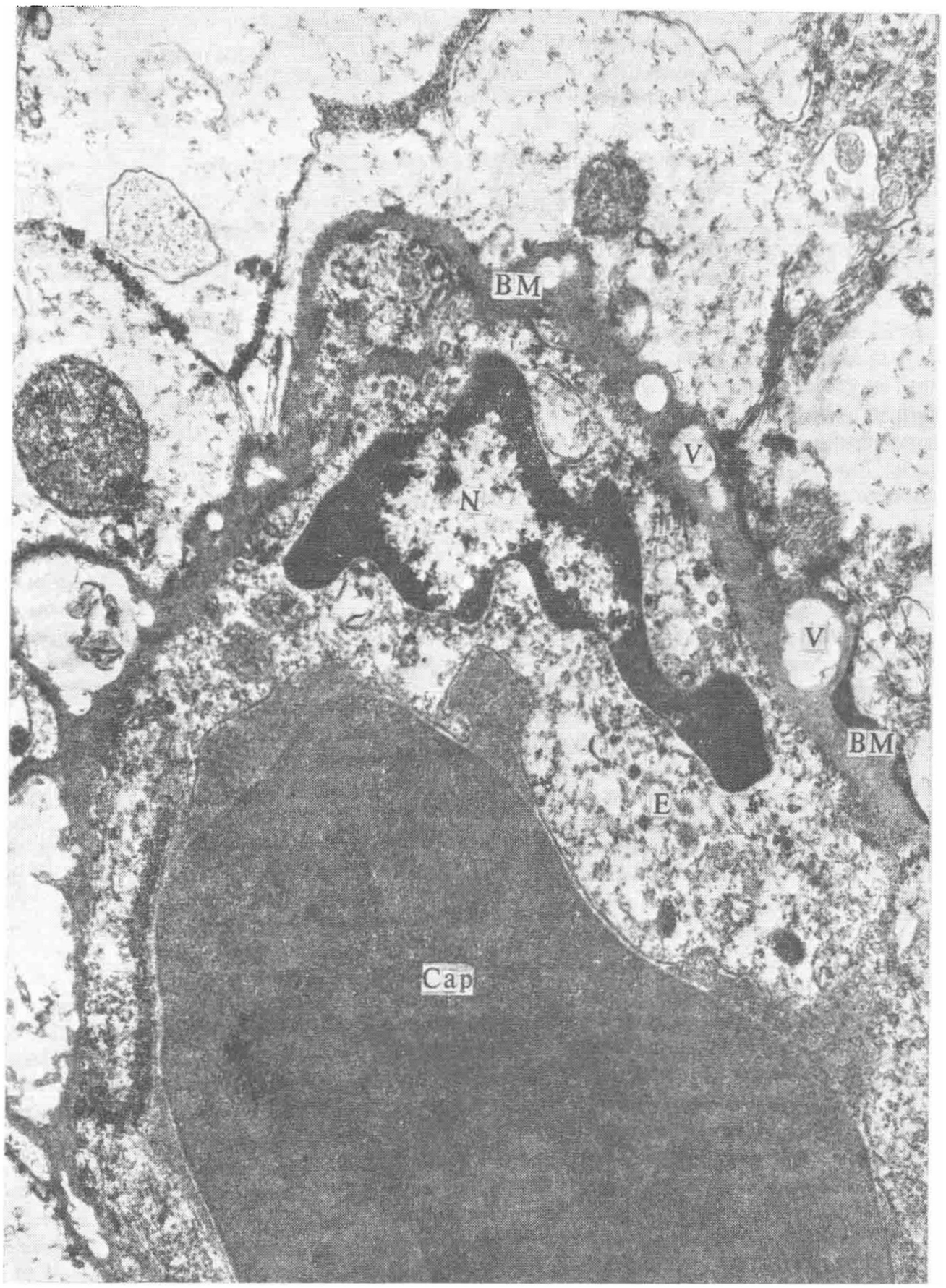


Fig. 45. Change in endothelial cells and the basal membrane of a capillary. A case of a fatal stroke: X40 000.

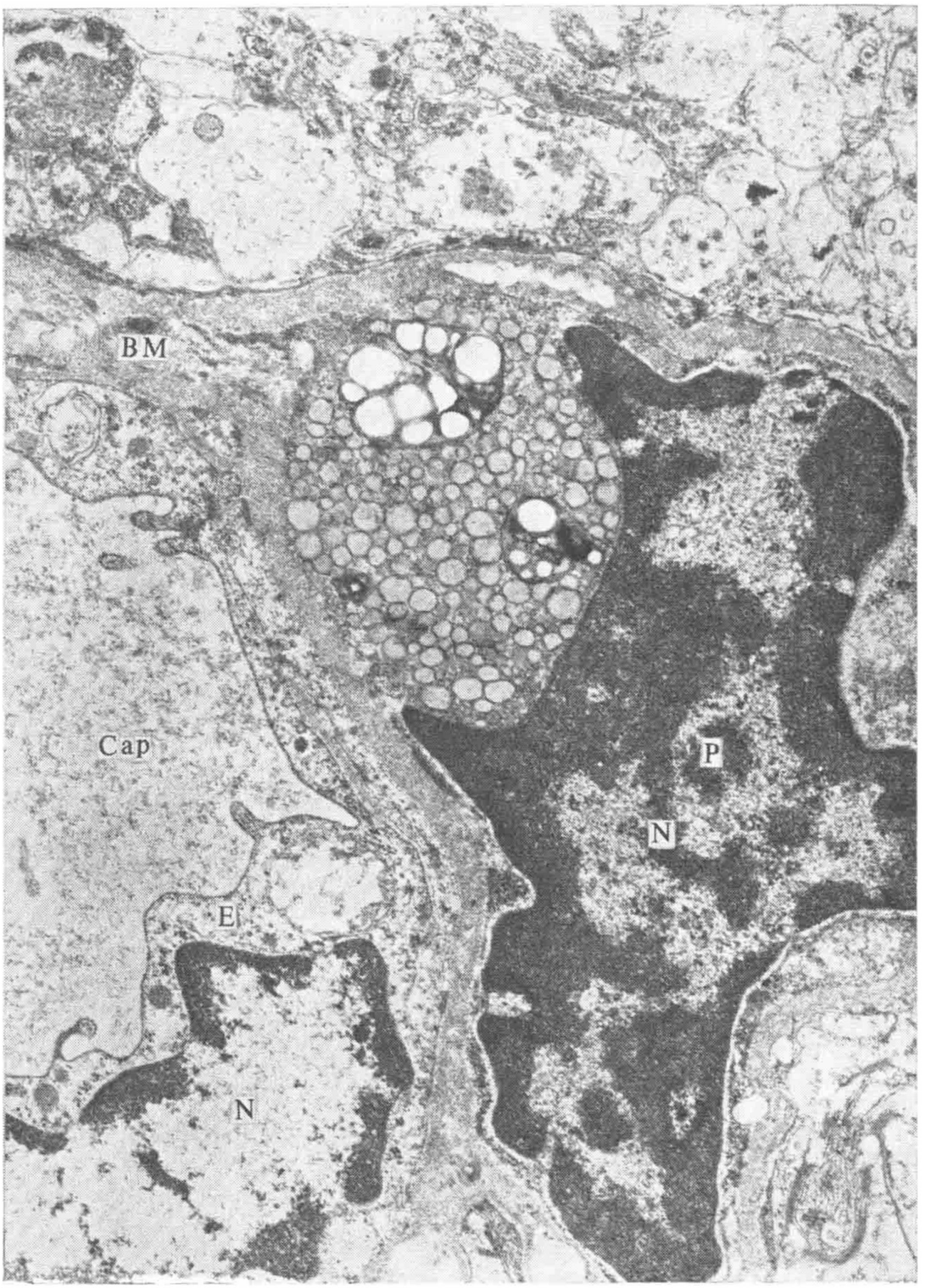


Fig. 46. Abnormal change of a capillary pericyte. A case of a fatal stroke; X40 000.

ders of the relevant neurons up to appearance of small foci of lost activity.

Analysis of changes in cell ultrastructure in disturbances of cerebral circulation has shown that the destructive transformation of the cell organelles occurs in a step-like fashion: until a certain period, in spite of developing severity of the process, the principal organelles are preserved to a certain degree to provide vital activity of the cells. Possible reversibility of the changes in the neurons depends on the degree of intracellular acidosis, the condition of the cytoplasm buffer systems, preservation of the mitochondria, etc. But when the cellular hypoxia reaches a certain critical level, then the mitochondria begin to disintegrate, the cytoplasm and nucleus transform irreversibly and the cell dies even when the circulation restores, and both oxygen and substrates are supplied sufficiently. The destructive process in such cells goes on, and they either disappear or undergo sclerosis and remain so comparatively long but eventually disintegrate as well.

4.8. The Clinical Picture of Haemorrhagic Stroke

Haemorrhagic stroke more often occurs between the ages of 45 and 60, the incidence being approximately equal for men and women. Typically, it develops all of a sudden, in the evening or afternoon, in the wake of excitement or essential fatigue. It is preceded sometimes with the rush of blood to the face, a headache, erythropsia. The *initial symptoms* are headache, vomiting, disorder of consciousness, accelerated respiration, brady- or tachycardia, hemiplegia or hemiparesis. The degree of disorder of consciousness may vary: *coma*, *sopor*, *stupefaction*.

In *coma*, the patient is unconscious, there is no reaction to stimuli, the eyes are closed, the gaze is otherwise unconcerned, the mouth is half-open, the face is hyperaemic, the lips are cyanotic; the vessels of the neck pulsate; respiration may be stertorous and periodic, of Cheyne-Stokes type, inhalation and exhalation are difficult, of different amplitude, rare; the skin is cold, the pulse is tense and decelerated, arterial pressure is rarely not increased; the pupils are often inadequate in size (sometimes the pupil on the side of the haemorrhage is dilated), there may be 'floating' or pendulum-like movements and a small divergence of the eyeballs, sometimes the gaze deviates to one side (paresis of the gaze), a corner of the mouth droops and the cheek bulges (the 'sail' syndrome) on the side of the paralysis; symptoms of hemiplegia are often seen in the contralateral side: outward rotated foot, dropping of the raised arm, pro-

nounced muscular hypotonia, decreased tendon and skin reflexes, the Babinski sign. Not uncommonly there are meningeal symptoms, vomiting, dysphagia, delayed or involuntary urination. Vast hemispherical haemorrhages are often aggravated by the secondary brain-stem syndrome. It is displayed by progressive disorders of respiration, cardiac activity, consciousness, and eye movements; the muscle tonus is changed by the type of hormetony and decerebrate rigidity; vegetative disorders are present as well. All those symptoms may appear both immediately after the stroke or some time after.

In *deep coma* all the reflexes disappear, muscular hypotonia is pronounced, disorders of the vital functions progress.

In *sopor* the patient usually lies with the eyes closed, does not answer any questions or answers very briefly, and responds only to the most simple instructions. There are vasomotor lability, chill-like tremor, sweating; these symptoms increase with the progress of disorder of consciousness. There are the focal symptoms. The pupil reaction to the light is preserved, the corneal reflex is preserved on the safe side. If the stroke does not concern the brain stem, then swallowing is normal, and the pharyngeal reflex is retained. The area of impairment of pain sensitivity may be ascertained by the patient's answers and reactions.

In *stupefaction* there are apprehension, anxiety, often motor excitation, delayed response, automatic movements in the safe limbs, the patient fails to carry out complicated instructions.

Hemiplegia, hemianaesthesia, hemianopsia (the internal capsule syndrome) are common when blood extravasates in the brain tissue towards the *internal capsule*. Haemorrhage into the *brain stem* is characterized by disorders of the vital functions, the symptoms typical of the damage to the nuclei of the cranial nerves and limb pareses, which sometimes occur as alternating syndromes. There are often strabismus (squint), anisocoria, mydriasis, fixed gaze, 'floating' movements of the eyeballs, nystagmus, dysphagia, the cerebellar symptoms, bilateral pyramidal reflexes. In *pontine* haemorrhages, there are myosis, paresis of the gaze towards the focus (the gaze is directed to the side of the paralysed limbs). Early rise in the muscle tonus (hormetony, decerebrate rigidity) occurs in haemorrhages into the *oral portions* of the brain stem. The foci in the *lower portions* of the brain stem are attended with early muscular hypotonia or atonia.

Cerebellar haemorrhage manifests itself in vertigo with a sensation of objects rotating, acute pain in the occipital and cervical areas, vomiting, myosis, the Hertwig-Magendie syndrome (skew deviation of the eyes), the Parinaud's syndrome (paralysis of convergence and vertical gaze, and unequal pupillary reactivity to light), nystagmus, scanning speech or dysarthria, muscular hypoto-

nia or atonia, ataxia, rigidity of the occipital muscles, but there is no paresis of limbs.

In *parenchymatous-ventricular haemorrhage*, disorders of consciousness increase, the vital functions are impaired, *hormetony* appears (periodic tonic spasms and a sharp rise in the muscle tone in the upper and lower limbs), while the tendon reflexes increase and both defensive and abnormal Babinski reflexes are present, etc.; the vegetative symptoms such as chill-like tremor, cold sweat, and hyperthermia develop.

In *subarachnoid haemorrhage*, first there is headache ('a blow into the back of the head'), then psychomotor agitation, vomiting, the meningeal symptoms, diminution of the tendon reflexes, a rise in temperature; sometimes an epileptic seizure may occur.

Several forms of development of haemorrhagic stroke are distinguished. The *acutest form* is characterized by an abrupt onset, within several minutes, of profound coma. The fatal outcome sets in quickly—in a matter of several hours. This is characteristic for extensive haemorrhage into the hemispheres, pons or cerebellum with extravasation of blood into the ventricles and damage to the vital centres of the medulla oblongata. The *acute form* develops suddenly, the patient's condition worsens within several hours, and in case the appropriate measures are not taken, the patient dies. Less often the condition becomes stable, then improves, but functions are not completely restored in most of such cases. This form of stroke is often observed with lateral haemorrhages. The *subacute form* is characterized by a slow progressing of the symptoms or by an acute onset with a subsequent short-time improvement and aggravation afterwards. Such a course of stroke is caused by a haematoma situated in the white matter.

The incidence of prolonged development of haemorrhagic stroke, when all phenomena develop within one or several hours, became more common for the past decades. The general cerebral symptoms are often indistinct. Cerebral haemorrhages in elderly and old patients develop less intensely than in young patients, often without pronounced general cerebral symptoms, not uncommonly without a temperature reaction or change in the blood.

Methods of study. The study of the *eye fundus* in haemorrhagic stroke may reveal haemorrhages into the retina, a picture of hypertensive retinopathy with oedema and haemorrhages.

The *clinical blood count* reveals leucocytosis, a shift of the differential blood count to the left, and a rise in the ESR. The following features are also noted: increased blood viscosity, polycythaemia, decreased capacity of platelets to adhesion and aggregation, a rise in fibrinolytic activity, increased plasma tolerance to heparin and elevated content of fibrinogen, hyperglycaemia, azotaemia, bilirubinaemia, decreased content of albumins, increased content of glo-

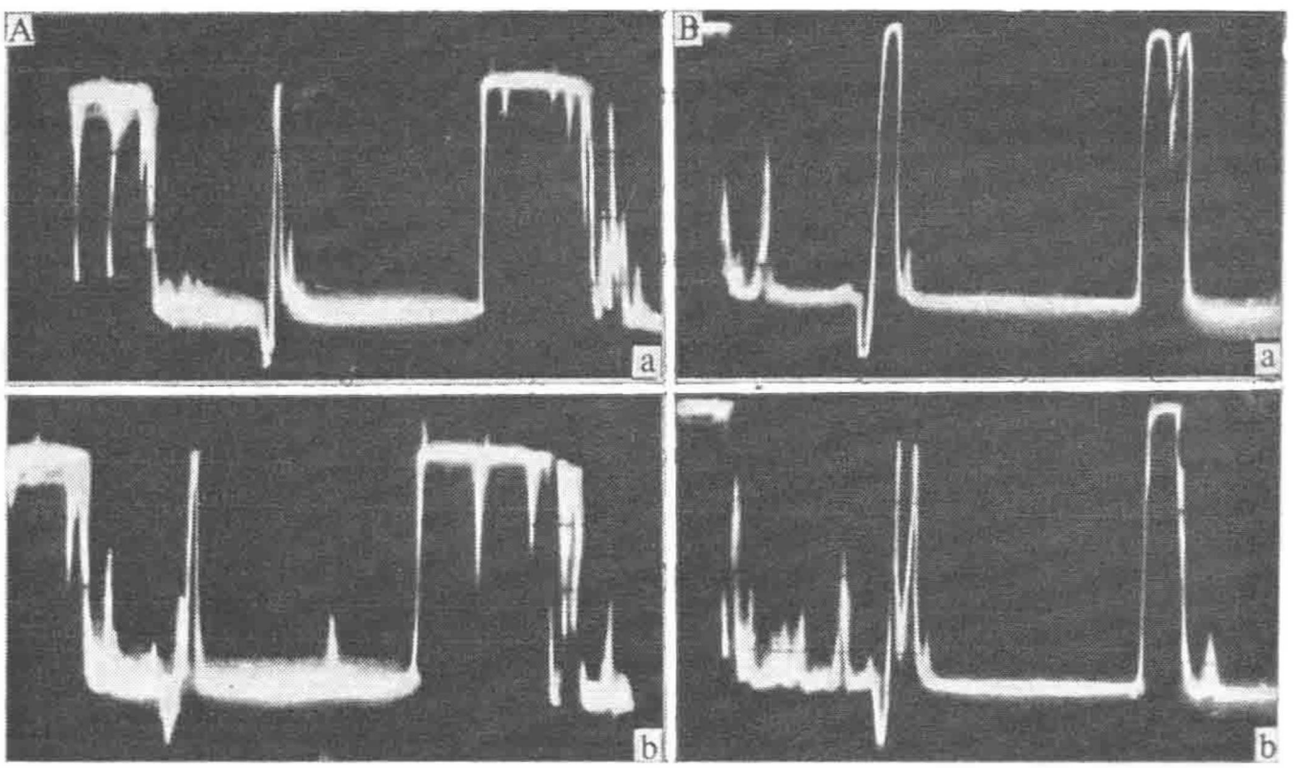


Fig. 47. Echoencephalograms.

A, an echoencephalogram of a patient with a haemorrhage into the left fronto-parieto-temporal area with extravasation of blood into the ventricles and subarachnoid space; the M-echo impulse is distinct, displaced 4 mm to the right, with a wide base. *B*, an echoencephalogram of a patient with subarachnoid-parenchymatous haemorrhage; the M-echo impulse is distinct, splitted like the letter M when the sensor is on the right side, displaced 1.5 mm to the left. Conclusion: intracranial hypertension, the focus in the right hemisphere. *a*—the sensor is on the left side, *b*—the sensor is on the right side.

bulins and 11-oxycorticosteroids, a decrease of potassium in blood and cerebrospinal fluid, an increase of chloride content. The study of the cerebrospinal fluid shows an admixture of blood in it. *Computer tomography* shows greater parenchymal density in the pertinent cerebral areas. *Echoencephalography* (Fig. 47) often establishes (in hemispherical strokes) a shift of the M-echo to the contralateral side. *Electroencephalograms* are characterized by gross diffuse changes in the brain biopotentials, sometimes with an interhemispheric asymmetry (Fig. 48). *Angiography* (Figs. 49, 50 and 51) may reveal displacement of intracerebral vessels or existence of a so-called 'avascular' zone as well as an aneurysm.

4.9. The Clinical Picture of Ischaemic Stroke (Cerebral Infarction)

General clinical data. Ischaemic stroke occurs most commonly in persons of middle age, elderly, and old people, but sometimes it may occur in young persons as well; its incidence is a little higher in men than in women. An onset of ischaemic stroke is not infrequent-

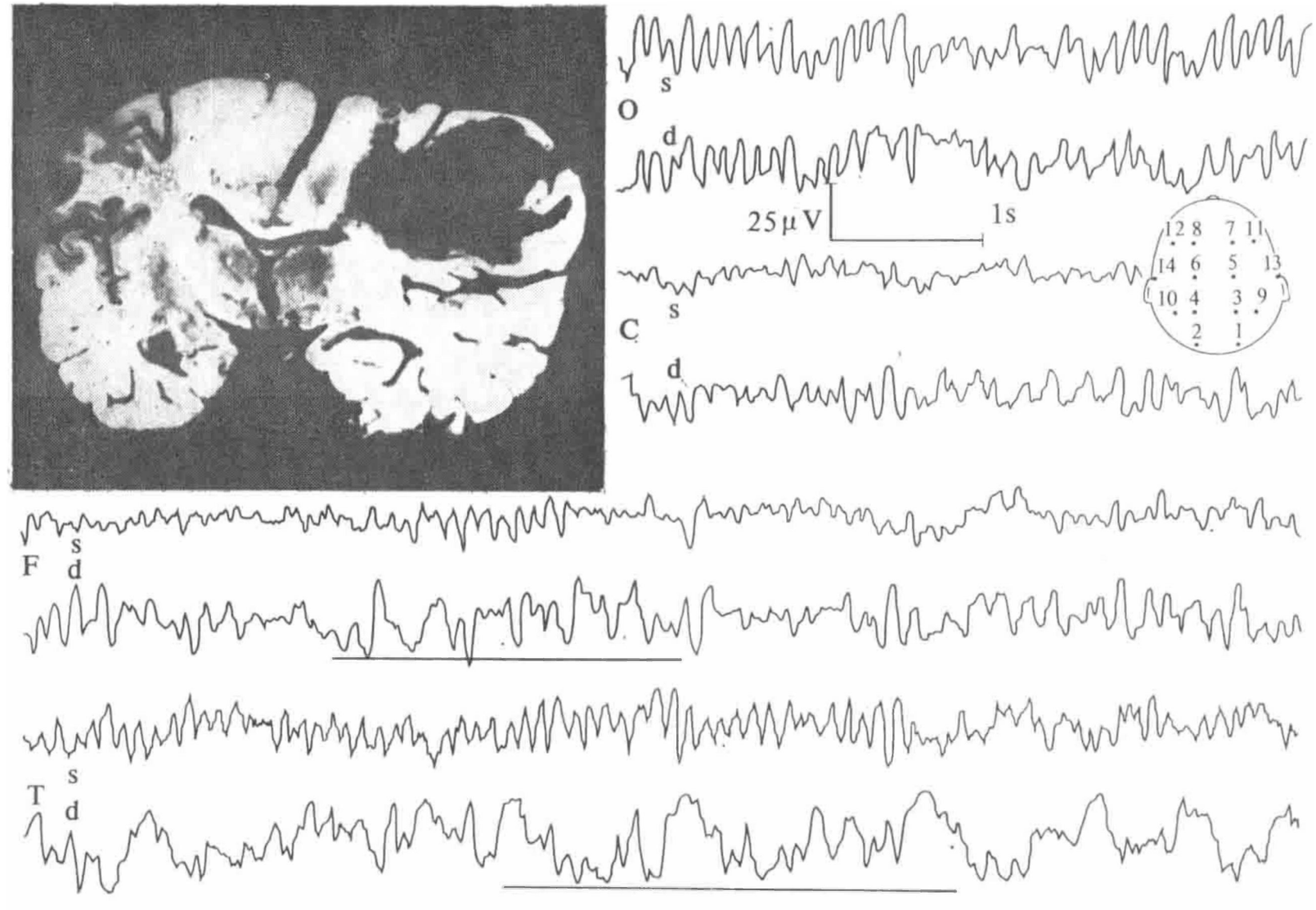


Fig. 48. Electroencephalogram of a patient with a haemorrhage into the white substance of the right cerebral hemisphere (localization of the focus is shown in the upper left part of the picture). The EEG reveals a focus of abnormal activity in the right fronto-temporal areas. Leads: monopolar, standard.

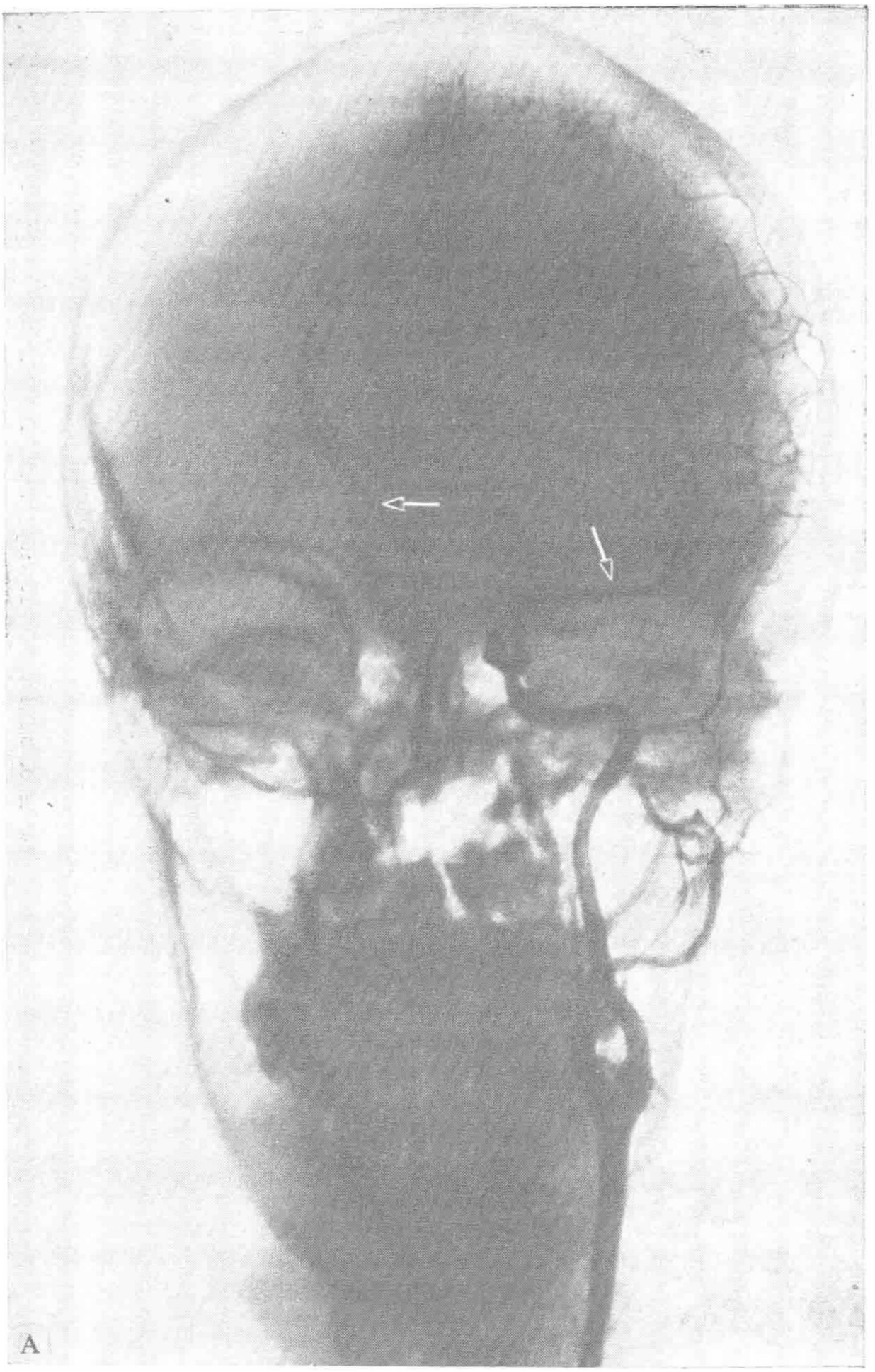
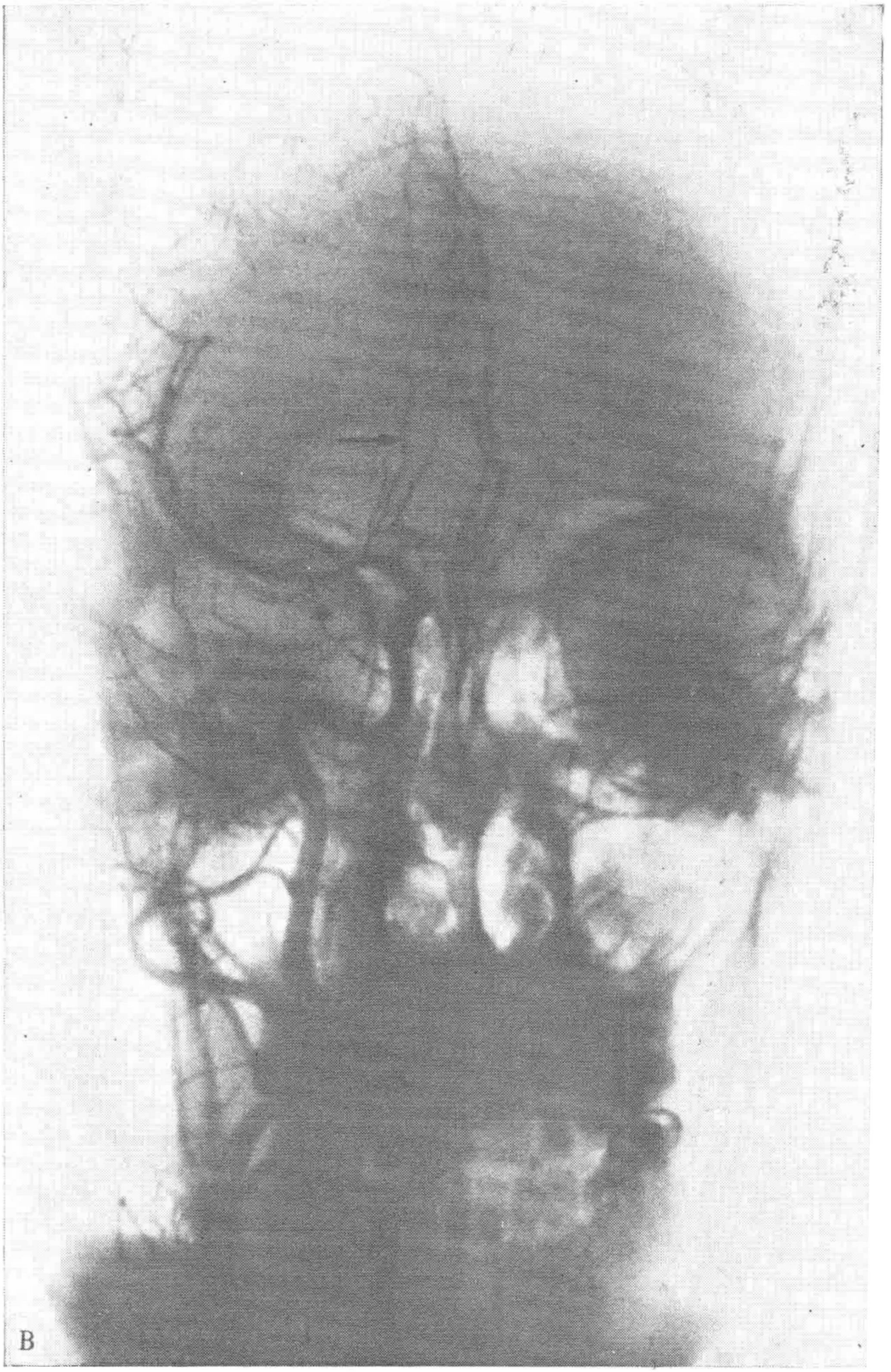


Fig. 49. Angiograms of patients with a haemorrhage by the type of haematoma.



A—displacement of the middle cerebral artery downwards and the anterior cerebral artery to the healthy hemisphere (the arrows); B—displacement of the anterior cerebral artery and the striated arteries to the healthy hemisphere.

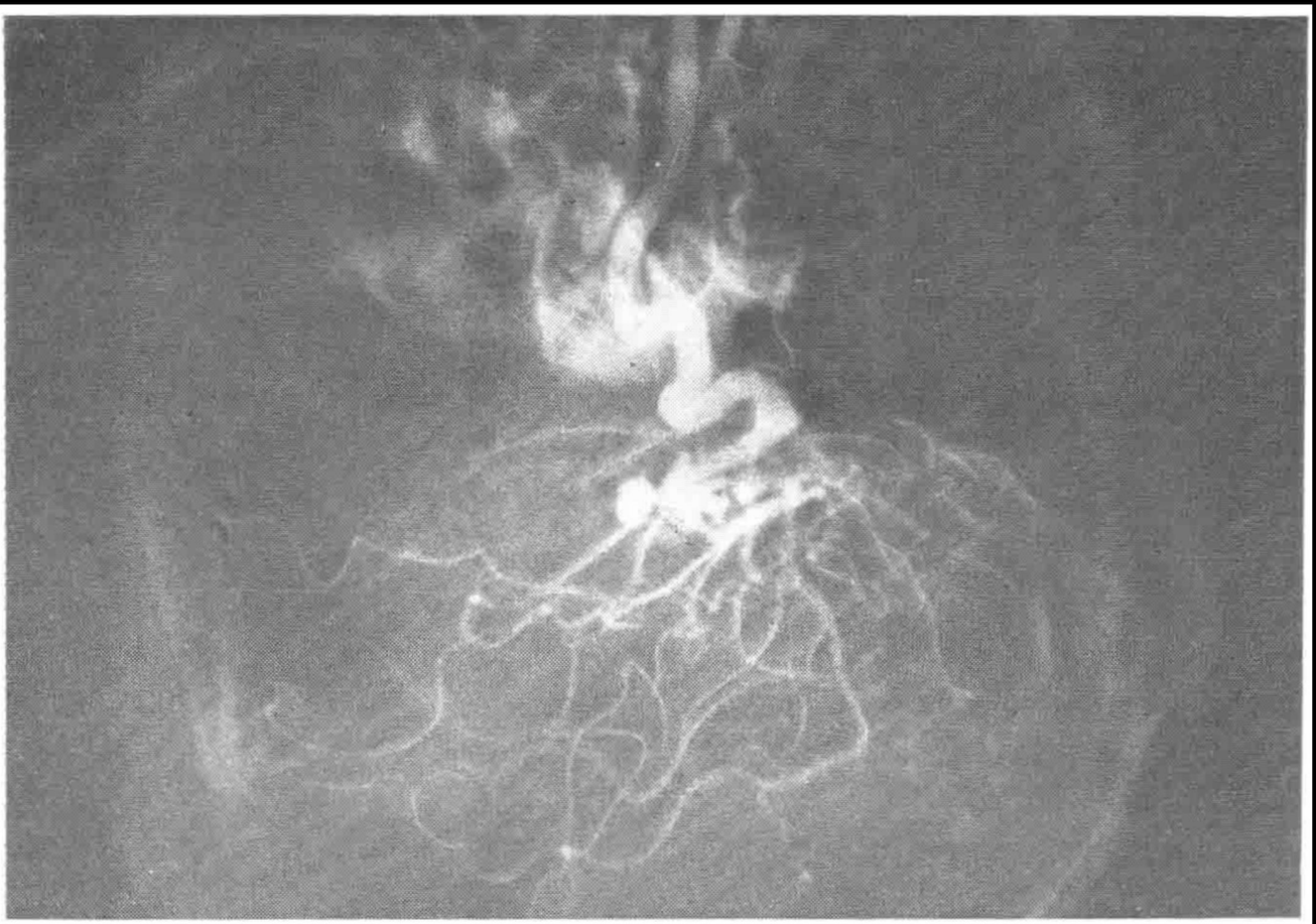


Fig. 50. Carotid angiogram. Saccular aneurysm in the supraclinoid portion of the carotid.

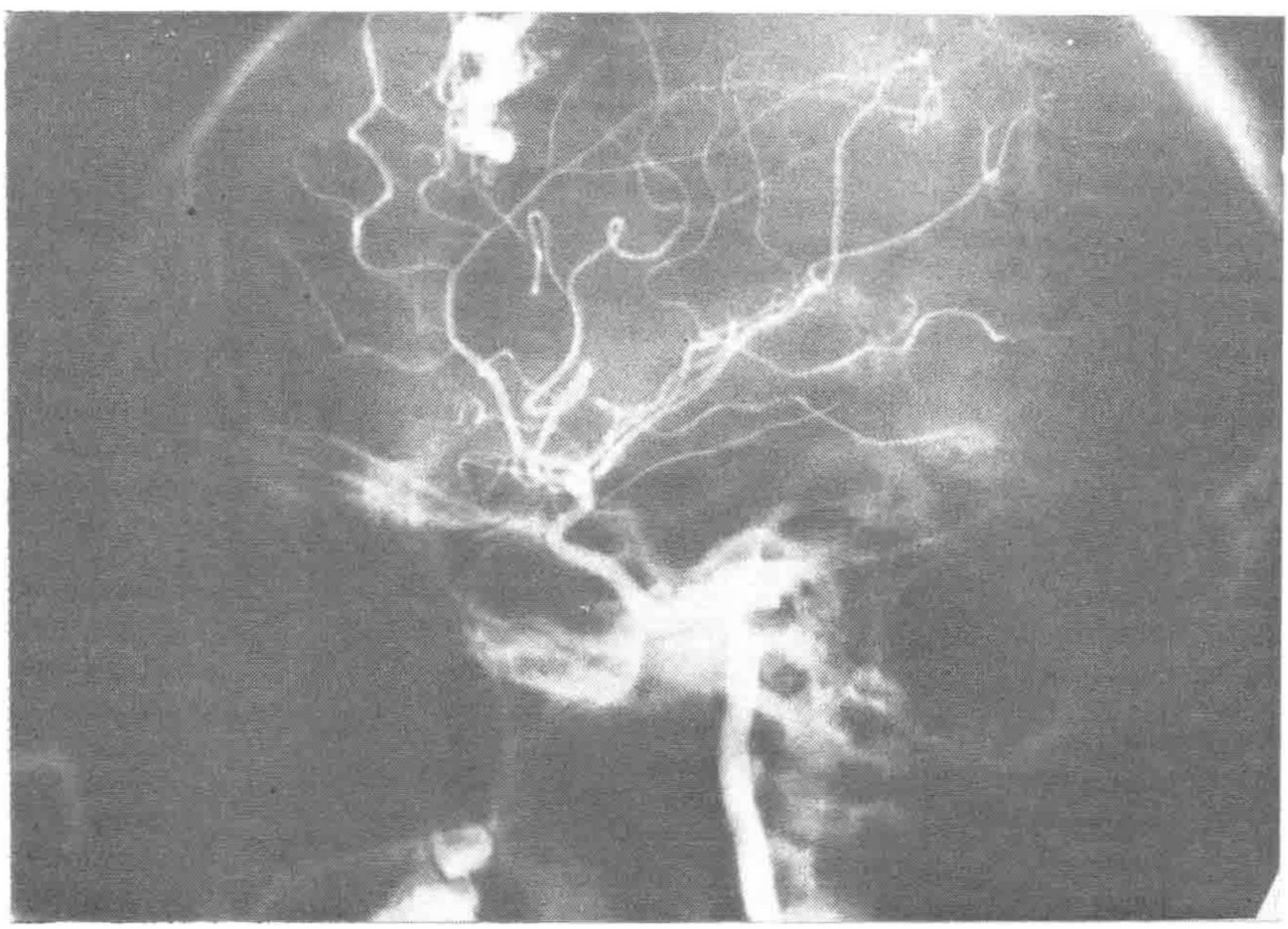


Fig. 51. Carotid angiogram. Arteriovenous aneurysm in the right frontal area.

ly preceded by transient disorders of cerebral circulation—the so-called transient ischaemic attacks, which are displayed by unstable focal symptoms. Typically, they are caused by a short-time deficit of blood supply into the area of the would-be infarction. In some of the patients, the transient ischaemic attacks occur more frequently immediately before the onset of cerebral infarction. When there is *thrombosis of cerebral vessels*, the following *prodromes* may be registered: dizziness, short-term disorder of consciousness (a semi-syncope), darkening before the eyes.

An ischaemic stroke may develop any time of the clock. Not uncommonly it occurs before sunrise or during the night-time. Early manifestations of stroke may sometimes be related to a physical overstrain, an emotional stress, hot bath, uptake of alcohol, blood loss, or to some disease, infections in particular. An ischaemic stroke often follows a myocardial infarction. A *gradual progress* of focal neurological symptoms is characteristic—over several hours, sometimes 2 or 3 days, seldom longer. *Undulating progress of symptoms* may be observed with alternating alleviation and deterioration ('waving' of the symptoms).

Ischaemic stroke develops by the *apoplectiform type* in one third of patients, when all the neurological symptoms appear at the same time, almost instantaneously and are fully pronounced at once. Such a clinical picture is especially typical of embolism, but it may be observed when some other mechanism is also responsible. The apoplectiform rise of extensive focal symptoms is not attended with pronounced general cerebral symptoms.

Acute development of ischaemic stroke may be observed in thrombosis of the intracranial portion of the internal carotid artery or in rapid occlusion of a large intracerebral artery and is displayed by a combination of focal symptoms with pronounced general cerebral symptoms.

In about one sixth of the patients cerebral infarction develops *slowly*, in the course of several weeks or even months. This kind of progress depends on the peculiarities of the occlusive process in the cerebral vessels, condition of collateral circulation and general haemodynamics. Slow development of cerebral infarction by the 'tumour' type may take place in combined lesion of the major arteries of the head. Such a development often occurs in the occlusive process in the both carotids in patients with pronounced cardiosclerosis.

It is characteristic for ischaemic stroke that *focal symptoms prevail over general cerebral ones*, the latter being sometimes absent. The focal symptoms are determined by localization of the infarct, diseased vessel, and collateral circulation.

The clinical syndrome provides a basis to assess localization and the size of the infarct, and to relate it to the area of some cerebral

artery. However, it is not always that the clinical features give grounds to decide whether they are due to an abnormality of a major or end artery, or whether they are caused by a complete or partial occlusion of the vessel. Reliable data may be obtained only by means of angiography.

The **clinical picture of lesion in the carotid.** Lesion in the *carotid system* is characterized by the following clinical features: prodromic undulation of symptoms, attacks of headache, transient disorder of vision, the Bernard-Horner syndrome on the side of thrombosis, *transient dyscirculatory carotid syndrome* (contralateral paresis, transient paraesthesia, numbness and hypaesthesia in the face and limbs, dysarthria, and aphasia when the lesion is in the left side), *transient alternating oculohemiparetic syndrome* (amblyopia on the side of thrombosis and contralateral hemiparesis of the limbs), *alternating asphygmohemiplegic syndrome* (a decrease of arterial pressure in the carotid of the affected side and a relative increase of pressure in the radial artery of the opposite side); epileptiform attacks, psychic changes; lower retinal pressure and atrophy of the optic nerve with stenosis of the vessels on the side of thrombosis; diminution or loss of the pulse in the carotid as determined by palpation, a bruit over the contralateral eye determined by auscultation, the *sinocarotid syndrome* (fluctuation of arterial pressure, attacks of tachycardia or bradycardia).

Infarctions in the basin of the internal carotid artery. The internal carotid supplies blood to the most part of the hemispheres —the cortex of the frontal, parietal, temporal areas, the subcortical white substance, the subcortical ganglia, the internal capsule. Abnormality of the carotid is encountered more often in men than in women. Atherosclerotic stenosis and thrombosis occur more often in the area of bifurcation of the carotids or in the sinus of the internal carotid artery, occasionally in the zone of the siphon. Occlusive lesion in the common or external carotids is less often. Sometimes there is a combined lesion in the external and internal carotids or in the both internal carotid arteries.

Abnormal tortuosity and kinks, which may lead to disturbances of cerebral circulation, are considered to be some of the forms of carotid lesion.

In adequate collateral circulation, the clinical symptoms and focal changes in the brain may be absent even when the internal carotid is completely occluded (in 15 per cent of the cases). This occurs usually when the lesion is in the extracranial portion of the internal carotid and the patency of the circle of Willis is unaffected, which ensures adequate substituting of blood flow from the contralateral internal carotid artery.

At the early stage, the clinical features of the occlusive lesion in the extracranial part of the internal carotid artery often take the

form of a transient disorder of cerebral circulation: short-time numbness and weakness in the limbs, occasionally aphatic disorders, hemiamblyopia or other symptoms. Disorders of cerebral circulation causing a persistent focal syndrome may be displayed in the following forms: (1) an acute apoplectic form with a sudden onset; (2) a subacute form which develops slowly, over several hours or a day or two; (3) a chronic pseudotumorous form which is characterized by a very slow aggravation of symptoms (over several days or even weeks).

Hemiplegia and hemihypaesthesia, as well as general cerebral symptoms, such as headache, vomiting, impairment of consciousness, psychomotor agitation, the secondary brain-stem syndrome, are distinctly pronounced in intracranial thrombosis of the internal carotid artery with concomitant dyscommunication of the circle of Willis.

The *anterior cerebral artery*. The surface branches supply the medial surface of the frontal and parietal lobes, the paracentral lobule, partially the orbital surface of the frontal lobe, external surface of the first frontal gyrus, the upper part of the central gyri and that of the superior parietal one, most of the corpus callosum (except its extreme posterior portions). Deep-going branches supply the anterior limb of the internal capsule, anterior portions of the head of the caudate nucleus, the putamen, the globus pallidus, part of the hypothalamic area, the ependyma of the anterior horn of the lateral ventricle.

Extensive infarctions rarely develop within the territory of the anterior cerebral artery. They may be caused by occlusion of its trunk past the branching of the anterior communicating artery, as well as by combined lesions in the vessels which might prevent compensating collateral circulation through the anterior communicating artery.

The clinical syndrome in extensive infarctions in the territory of the anterior cerebral artery is characterized by spastic paralysis in the contralateral limbs—the proximal part of the arm and distal part of the leg. Retention or incontinence of urine is not uncommon. The grasping reflexes and the symptoms of oral automatism are typical. In case the foci are bilateral, there appear psychic disorders, aspontaneity, impairment of self-criticism, elements of antisocial behaviour, deterioration of memory, etc. When the focus is in the left side it may evoke apraxia in the left arm due to the lesion in the corpus callosum. There may be slight impairment of sensitivity in the paralysed leg.

Limited infarcts are more common in the area of the anterior cerebral arteries, because of peculiarities of collateral circulation and an uneven lesion in their end arteries. Impairment in the area of the paracentral branch commonly gives rise to foot monoparesis similar to peripheral paresis. In involvement in the process of the

area supplied by the paracallosum branch left-sided apraxia may occur. In case of a lesion in the premotor area and the pertinent conducting pathways, the so-called pyramidal split syndrome appears, where the degree of spasticity substantially prevails over that of paresis, and the tendon reflexes are sharply increased with the abdominal reflexes being retained. Among abnormal reflexes, the reflexes of the flexion type are predominant.

The *middle cerebral artery* has the following branches: (a) the deep ones (the largest is the a. lenticulo-striata) which stem from the initial part of the trunk of the middle cerebral artery and supply a considerable part of the subcortical ganglia and of the internal capsule; (b) the cortical branches: the anterior temporal branch, stemming from the initial part of the trunk of the middle cerebral artery and supplying most of the temporal area; ascending branches, stemming from the common trunk: oculofrontal, precentral (prerolandic), central (rolandic), anterior parietal branches; posterior parietal, posterior temporal branches, and the branch, supplying the angular gyrus.

Cerebral infarction affects the territory of the middle cerebral artery most frequently. Not uncommonly, cerebral infarction occurs due to some occlusive process in the carotid artery, without any pronounced pathology of the middle cerebral artery proper.

A lesion in the trunk of the middle cerebral artery prior to the origin of its deep branches affects the whole of its territory, causing 'total' infarction; occlusion of the same artery past the origin of its deep branches affects the area of the cortico-subcortical branches, causing extensive cortico-subcortical infarction.

Total infarction involves the posterior portions of the frontal gyri, inferior two thirds of the precentral and postcentral gyri, the opercular area, a considerable part of the parietal and frontal areas, the insula, the semioval centre, the internal capsule (partially the anterior limb, the genu, the anterior part of the posterior limb), subcortical ganglia and a part of the thalamus. The territory of the posterior branches of the middle cerebral artery can be affected usually only when there is a concomitant lesion in the vertebrobasilar system or the posterior cerebral artery.

The clinical syndrome of total infarction includes contralateral hemiplegia, hemianaesthesia, and hemianopsia. Aphasia (of the mixed type or total) occurs in infarction in the left hemisphere and anosognosia occurs when the right hemisphere is affected. Infarction in the area of the deep branches causes spastic hemiplegia, inconstant impairment of sensitivity. If the focus is in the dominant hemisphere, a short-term motor aphasia may appear.

Extensive cortico-subcortical infarction causes hemiplegia or hemiparesis with prevailing disorder of arm function, impairment of all kinds of sensitivity, hemianopsia. Infarction in the dominant

hemisphere brings about aphasia, either total or of the mixed type, acalculia, agraphia, alexia, apraxia. When the focus is in the right hemisphere, the acute period of stroke may often be characterized by anosognosia (lack of awareness of an illness) and/or autotopagnosia (disorders of the body schema), e.g. loss of the sense or power of localization or orientation so far as bodily regions or parts are concerned.

Infarction in the territory of the common trunk of the ascending branches causes hemiplegia or hemiparesis with prevailing disorder of the arm function, hemihypaesthesia of the cortical type, and when the focus is in the left hemisphere, motor aphasia may occur as well.

Infarction in the area of the posterior branches of the middle cerebral artery evokes the so-called parieto-temporo-angular syndrome which includes hemianopsia (actually either in a half-side or in a lower quadrant) and hemihypaesthesia with astereognosis. Afferent paresis of the limbs may occur due to impairment of sensitivity, especially deep one. Sensory or amnestic aphasia, apraxia, acalculia, agraphia, and finger agnosia may appear, apart from the above-mentioned symptoms, in case the focus is in the left side. Disorder of the body schema may occur in patients with a right-sided lesion.

Symptoms of infarction in the areas of individual branches of the middle cerebral artery are more limited. Infarction in the area of the precentral artery leads predominantly to paresis in the lower part of the face, the tongue, and the masticatory muscles, with concomitant motor aphasia if the focus is left-sided. Bilateral focus in this area causes the pseudobulbar syndrome with dysarthria, dysphagia, and aphonia.

Infarction in the area of the rolandic artery results in hemiplegia or hemiparesis, the latter predominantly in the arm. Infarction in the area of the posterior parietal artery brings about hemihypaesthesia or hemianaesthesia including all kinds of sensitivity, sometimes with 'afferent' paresis. This syndrome has been named pseudothalamic, but there is no pain characteristic for a lesion in the thalamus.

The *anterior artery of the vascular plexus* contributes to blood supply of the posterior two thirds of the posterior limb of the internal capsule, and sometimes of its retrolenticular part, the caudate nucleus, internal segments of the globus pallidus, lateral side of the inferior horn of the lateral ventricle. The pertinent clinical syndrome includes hemiplegia, hemianaesthesia, occasionally hemianopsia, vasomotor disorder in paralysed limbs, Aphasia does not occur in this case, unlike infarction in the territory of the middle cerebral artery.

The **clinical picture of lesions in the vertebrobasilar system.** The syndrome of occlusion of the vessels of the vertebrobasilar sys-

tem includes systemic vertigo, unsteady gait, nystagmus, tinnitus, impairment of hearing and vision, attacks of 'falling', vegetative disorders, the Wallenberg-Zakharchenko syndrome, cerebrovisceral disorders, attacks of adynamia, ataxia, asynergy of the torso and the limbs, scanning speech, transient brain-stem and visual disorders, lesions in the pathway systems (the pyramidal, sensory, cerebellar ones). Aggravation of the symptoms with a turn of the head is characteristic. Occasionally, coma may develop, tetraplegia, general symptoms, impairment of respiration and a change in arterial pressure; the muscle tone may be decreased or there may be hormetony.

Infarctions in the area of the vertebrobasilar system. The *posterior cerebral artery.* Cortico-subcortical branches of the posterior cerebral artery supply the cortex and subcortical white substance of the occipitoparietal area, and posterior and mediobasal portions of the temporal area. The deep branches (thalamoperforating, thalamogeniculate, premammillary) supply a considerable part of the thalamus, the posterior portion of the hypothalamic area, the bulb of the corpus callosum, optic radiation and the body of Luys (the subthalamic nucleus); there are small branches also to the midbrain.

Infarctions in the territory of the posterior cerebral artery arise both due to circulation arrest in the artery proper or in its branches; they may also be caused by lesions in the basilar or vertebral arteries. Their combined lesion is not uncommon. The branches of the posterior cerebral artery have anastomoses with other arteries (the middle one, anterior one, villous ones, branches of the basilar arteries). Therefore total infarctions are very much unlikely.

Infarction in the area of the cortical branches of the posterior cerebral artery may involve the whole occipital lobe, the third and partially the second temporal gyri, the basal and the mediobasal gyri of the temporal lobe (in particular the hippocampal gyrus). The following clinical features are characteristic: homonymous hemianopsia (with 'macular sparing') or hemianopsia in the upper quadrant; less often there are phenomena of metamorphopsia and/or visual agnosia. In the left-sided infarctions alexia or mildly pronounced sensory aphasia may be encountered.

The spread of the infarction into the mediobasal portions of the temporal area, especially in bilateral lesion, results in pronounced impairment of memory by the type of the Korsakov syndrome with predominant affection of a short-term memory and in emotional disorders. Sometimes they are preceded by transient amnesia.

Infarction in the area of the thalamogeniculate artery involves the external part of the ventrolateral nucleus of the thalamus, the ventral posterolateral nucleus, lower two thirds of the caudate nucleus, most of the pulvinar of the thalamus, and the lateral genicu-

late body. The clinical picture is characterized by the Déjérine-Roussy syndrome: hemihypaesthesia or hemianaesthesia, hyperpathia and dysaesthesia, contralateral thalamic pains and transient hemiparesis; inconstant hemianopsia, hyperkinesis of the pseudoathetoid or choreoathetoid type, hemiataxia, trophic and vegetative disorders.

Infarction in the territory of the thalamoperforating artery destroys the posterior part of the hypothalamic area, the dorsomedial nucleus of the thalamus, the Luys medial nucleus, the body of Luys, the dentatorubrothalamic tract. The clinical syndrome involves ataxia and intentional tremor in the contralateral limbs (the superior syndrome of the red nucleus). Occasionally, there may be hyperkinesis of the choreoathetoid type or hemiballism instead of arm tremor. A 'thalamic' hand may also be observed: the forearm is bent and pronated, the hand is also bent, the fingers are slightly bent in the metacarpophalangeal joints, but the middle and terminal phalanges are extended.

The *basilar artery* has branches to the pons and cerebellum, and bifurcates into the two posterior cerebellar arteries. In 70 per cent of the patients a complete occlusion (thrombosis) in the basilar artery is preceded by recurrent transient disorders of circulation in the vertebrobasilar system—attacks of dizziness, dysarthria, transient pareses and paralyses in the limbs, craniocerebral nerves and other symptoms. An acute occlusion results in the symptoms of predominant lesion in the pons with impairment of consciousness up to coma. The following symptoms gradually develop over several hours or within two to five days: bilateral paralysis of the craniocerebral nerves (third, fourth, fifth, sixth, seventh), the pseudobulbar syndrome, paralysis of the limbs (hemi-, para- or tetraplegia), impairment of the muscle tone (transient hormetonic convulsions, decerebrate rigidity followed by muscular hypotonia and atonia). Occasionally there are cerebellar symptoms, 'cortical blindness' (the basilar artery bifurcation syndrome). Bilateral abnormal reflexes and trismus are often encountered. There may be vegetovisceral crises, hyperthermia, impairment of the vital functions. The outcome in most of the cases is fatal, not uncommonly over the first several minutes or hours of such a stroke. In rare cases the stroke may take a milder course or even have a favourable outcome, when an anastomosis develops between the superior and inferior cerebellar arteries.

The *vertebral artery* supplies the medulla oblongata, partially the cervical portion of the spinal cord, and the cerebellum. Disorders of cerebral circulation in the territory of the vertebral artery are often caused by atherosclerotic stenosis, thrombosis, vertebrogenic dislocations and compressions, abnormal tortuosity and kinking. Occlusion in the vertebral artery may be followed by development

of infarction foci not only in the territory of the medulla oblongata and cerebellum, but also in the distal areas supplied by the basilar and posterior cerebral arteries.

Occlusion in the extracranial portion of the vertebral artery is characterized by a 'spotted' lesion in various parts of the vertebrobasilar system. Commonly these are vestibular disorders (vertigo, nystagmus), impairment of posture and coordination of movements, visual and oculomotor disorders, dysarthria; pronounced motor and sensory disorders are less common. In some patients there are sudden attacks of falling down with loss of the postural tone (drop attacks), adynamia and hypersomnia. Dyscirculation in the mesoencephalic portions and mediobasal areas of the temporal lobe leads to memory disorder by the type of the Korsakov syndrome.

Occlusion in the intracranial portion of the vertebral artery is characterized by combination of persistent alternating syndromes of the medullary lesion with transient ischaemic symptoms in the oral division of the brain stem and in the occipital and temporal lobes. The Wallenberg-Zakharchenko, Babinski-Nageotte, and other syndromes of a unilateral lesion in the inferior parts of the brain stem develop in about 75 per cent of the cases. Bilateral thrombosis of the vertebral artery causes dysphagia, aphonia, disorders of respiration and cardiac activity.

The **brain-stem arteries.** The brain stem is supplied by the branches of the basilar and vertebral arteries, as well as by the posterior cerebral artery. They have three groups of branches; the paramedian arteries which supply mainly the base of the middle portion of the brain stem, the short circumflex arteries which supply the lateral divisions of the brain stem, and the long circumflex arteries supplying the dorsolateral parts of the brain stem and the cerebellum.

Infarctions in the brain-stem area result from lesions in the vertebrobasilar system at different levels. Sometimes a lesion in a major vessel is responsible, in other cases an end artery; their combined lesion is a common occurrence. It is typical of an ischaemic lesion in the brain stem that there are several disseminated, usually small, foci of infarct which in different cases impart considerable polymorphism to the clinical signs.

The **arteries of the midbrain.** The paramedian arteries branch from the posterior cerebral and basilar arteries and predominantly supply the middle and median parts of the cerebral peduncles (the pyramidal tract, substantia nigra, red nucleus, superior peduncle of the cerebellum, nuclei of the third and fourth pairs of the craniocerebral nerves, and posterior longitudinal fascicle).

Infarction in the area of these arteries often leads to the inferior nucleus ruber syndrome (the Claude-Loyez syndrome—ipsilateral paralysis of the oculomotor nerve, ataxia) and to intentional tremor in the contralateral limbs (due to a lesion in the fibres of the supe-

rior peduncle of the cerebellum from the Wernekinck commissure up to the red nucleus or due to a lesion in the red nucleus proper); choreiform hyperkinesis may be seen sometimes as well. When the oral portions of the red nucleus are involved, the oculomotor nerve may not be affected; this is the case of the superior nucleus ruber syndrome. Infarct involving the base of cerebral peduncles causes the Weber syndrome. A lesion in the posterior longitudinal fascicle brings about paralysis or paresis of gaze with occasional concomitant nystagmus.

The short circumflex arteries of the midbrain (the posterior arteries of the vascular plexus) supply the lateral portions of the cerebral peduncles. Infarction in the area may result in paresis of the contralateral limbs, or in contralateral hemihypaesthesia. The long circumflex arteries of the midbrain are branches of the superior cerebellar artery (branches of the basilar artery) and of the quadrigeminal artery (branches of the posterior cerebral artery). They supply the superior peduncle of the cerebellum, spinothalamic fascicle, partially the lateral and medial ansae, the central fascicle of the operculum, the mesencephalic root of the trigeminal nerve, the reticular substance, partially the quadrigeminal bodies. The clinical signs of infarction in the area of the superior cerebellar artery may include ipsilateral choreiform or athetotic hyperkinesis, contralateral impairment of pain and thermal sensitivity, occasionally myoclonia of the soft palate. Infarction in the area of the quadrigeminal artery causes symptoms of a lesion in the nuclei of the oculomotor nerve up to complete ophthalmoplegia, as well as paresis or paralysis of gaze. Especially characteristic are paralysis of the upward gaze and paresis of convergence (the Parinaud syndrome, or the syndrome of the posterior commissure). There are often cerebellar symptoms. In extensive, especially bilateral, infarcts in the midbrain area or lesions in the nucleus of the reticular formation, consciousness and sleep-wake timing are impaired. Occasionally, there is 'peduncular hallucinosis' with mainly visual hallucinations of the hypnagogic type: the patient sees moving coloured figures of people, animals, etc., but retains his critical attitude to them.

The **pontine arteries.** The paramedian arteries branch from the basilar artery and supply the pontine basis: the pyramidal tracts, grey nuclei of the pons, pontine fibres and a part of the medial lemniscus. The nucleus of the abducent nerve in the tegmentum may sometimes be affected. Infarction in the area is characterized by contralateral hemiplegia and central paralysis of the facial and hypoglossal nerves (the medial pontine syndrome). The muscular tone in the paralysed limbs in the early period after the onset of a stroke is usually flaccid, the defensive reflexes are either lost or slightly pronounced. When infarct is localized in the inferior portion of the pons, there may be paresis of gaze of the pontine type (the gaze is

deviated towards the paralysed limbs) or ipsilateral paralysis of the abducent nerve. Occasionally, that is accompanied with paralysis of the facial nerve in the same side (the alternating Foville syndrome). Bilateral infarct in the area of the paramedian pontine arteries results in tetraplegia or tetraparesis, pseudobulbar and cerebellar symptoms. Localized infarct in the basis of the pons may bring about mild hemiparesis, sometimes monoparesis of limbs, sometimes only pseudobulbar symptoms. This may be explained by the fact that both the pyramidal and the corticobulbar tracts are present there as separate fascicles among the cells and fibres of the pons proper.

The short circumflex arteries branch from the basilar artery and supply the lateral portions of the pons, the cerebellar peduncle, sometimes the spinothalamic tract, and the lateral parts of the medial lemniscus and of the pyramidal tract. Infarction in the area of these branches evokes development of the lateral syndrome of the pons. Infarction in the middle third of the lateral part of the pons may include a lesion in the nucleus of the trigeminal nerve; when the focus is in the inferior third of the lateral portion of the pons, the nucleus of the facial nerve may be affected. The clinical signs are: the homolateral cerebellar syndrome with impairment of sensitivity, and sometimes contralateral pyramidal signs; the Bernard-Horner syndrome may occur on the side of lesion.

Foci in the medial and inferior thirds of the lateral part of the pons due to lesions in the sensory nucleus, the gelatinous substance of the trigeminal nerve, and the spinothalamic fascicle bring about ipsilateral disorders of the pain and thermal sensitivity of the face, and contralateral impairment of these kinds of sensitivity in the trunk and limbs (alternating hemihypaesthesia or hemianaesthesia). A focus in the inferior third of the lateral part of the pons may cause ipsilateral peripheral paralysis of the facial nerve along with the principal syndrome.

The long circumflex arteries of the pons are branches of the three cerebellar arteries: the superior, middle and anteroinferior ones. Infarction in the oral portions of the tegmentum of the pons in the territory of the superior cerebellar artery involves the superior peduncle of the cerebellum, the spinothalamic fascicle, the central pathway of the tegmentum, partially the posterior longitudinal fascicle. The clinical symptoms are: contralateral disorders of pain and thermal sensitivity, ipsilateral cerebellar disorders, paresis of gaze of the pontine type, occasionally nystagmus when the gaze is deviated to the side of lesion. All that may be accompanied with ipsilateral hyperkinesia of the choreiform or athetotic type and the Horner syndrome, sometimes with the myoclonic syndrome. Concomitant dyscirculation in the short circumflex arteries of the pons may bring about a lesion in the nucleus of the trigeminal nerve, thus

leading to the syndrome of alternating hemihypaesthesia or hemianaesthesia. Infarction in the caudal part of the pontine tegmentum, which is supplied by the anterior inferior cerebellar artery and the short circumflex ones, causes ipsilateral cerebellar symptoms, dissociated impairment of sensitivity in the side of the body opposite to the lesion, and occasional peripheral paralysis of the ipsilateral facial nerve.

Bilateral infarct in the area of the pontine tegmentum evokes the pseudobulbar syndrome. Extensive infarct in the area, when the activating sections of the reticular formation are affected, results in loss or impairment of consciousness of various degree (coma, sopor, stupefaction, akinetic mutism). Akinetic mutism is a term applied to a specific condition of the patient who has no paralysis, yet still lies immobile with eyes open, does not speak, does not come into contact with anybody, yet the eyes follow the objects in front of them, and both pain and sound stimulation may bring a motor response. Loss of active movements and speech in that case appears to be due to disorder of motivation for action and impairment of motor integration associated with a lesion in the activating portions of the reticular substance of the brain stem. Akinetic mutism occurs in some cases of an isolated lesion in the pontine tegmentum; commonly the tegmentum of the midbrain is affected as well.

The **arteries of the medulla oblongata.** The paramedian arteries in the oral portion of the medulla branch from the vertebral arteries and in the caudal portion from two anterior spinal arteries; they supply pyramidal tract, medial lemniscus, supranuclear fibres, and the nucleus of the hypoglossal nerve. Infarction in this area results in the medial syndrome of the medulla—paralysis of the ipsilateral hypoglossal nerve and paralysis of the contralateral limbs (the Jackson syndrome). Sometimes only the pyramidal tract is affected, either unilaterally or bilaterally, leading accordingly to uni- or bilateral spastic paralysis. Cross paralysis of an arm and the opposite leg occurs very seldom when the pyramidal tract is affected laterally to the decussation.

Infarct in the area of the arteries of the lateral fossa of the medulla, branching from the vertebral arteries, involves the superior portions of the bulbar part of the restiform bodies, the superior portion of the motor nucleus of the ninth and tenth pairs of the craniocerebral nerves, the arch-like fibres, superior halves of the bulbar olives, the central pathway of the tegmentum, the descending root of the trigeminal nerve or its gelatinous substance. Clinically, this evokes the Babinski-Nageotte syndrome, very much like the Wallenberg-Zakharchenko syndrome: paralysis of the posterior veil of the soft palate (the vocal cord function being intact), cross hemiparesis with impairment of pain and thermal sensitivity, and cerebellar ataxia in the side of lesion.

The inferior posterior cerebellar artery, which is the largest branch of the vertebral artery, serves as the long circumflex artery of the medulla. It supplies the cerebellum and the retro-olivary lateral portions of the medulla (the restiform body, the area of the vestibular nuclei, the descending nucleus and the root of the trigeminal nerve, the spinothalamic tract, the nuclei of the glossopharyngeal and vagus nerves). Infarction in this area develops as the result of occlusion in the vertebral and/or inferoposterior cerebellar arteries. The clinical picture is characterized by the Wallenberg-Zakharchenko syndrome which is the lateral syndrome of the medulla oblongata. There is paralysis of the muscles of the larynx, throat, and soft palate (due to lesion in the nuclei of the ninth and tenth pairs of the craniocerebral nerves); disorder of sensitivity of the face, often by the 'bulbar' type with a lesion in the external Selder zones (due to a lesion in the nucleus of the descending root of the trigeminal nerve), cerebellar disorders (due to a lesion in the cerebellum and/or its inferior peduncle), the Horner syndrome (due to a lesion in the hypothalamospinal sympathetic tract). Since the spinothalamic tract is affected, the contralateral limbs and the same side of the trunk suffer from disorders of pain and thermal sensitivity; the upper border of the impairment may vary. The deep and tactile sensitivity are retained. The symptoms of lesion in the pyramidal tract are either absent or moderately pronounced in the contralateral side. Common symptoms are dizziness and nystagmus due to a lesion in the vestibular nuclei; nystagmus is greater when the eyes deviate ipsilaterally. Patients with the Wallenberg-Zakharchenko syndrome may vomit persistently, some have ipsilateral burning pain in the face, which appears to be due to a lesion in the gelatinous substance of the descending root of the trigeminal nerve.

There are a number of variants of that syndrome, which is accounted for by the variety of the course of the inferoposterior cerebellar artery and by the variety of collateral circulation in the different patients. The variants are as follows:

1. Ipsilateral paralysis of the soft palate, the vocal cord, impairment of pain and thermal sensitivity in the face, the Horner symptom, ataxia in the limbs; contralateral disorder of sensitivity of the dissociated type in the trunk and limbs.
2. The same syndrome as in variant 1 with a concomitant lesion in the sixth and seventh pairs of the ipsilateral craniocerebral nerves.
3. The same syndrome as in variant 1 with concomitant cross hemiplegia or triplegia (in caudal lesion).
4. The same syndrome as in variant 1, but disorder of sensitivity of the dissociated type involves the whole contralateral part of the body, including the face; ipsilateral sensitivity in the face is retained.

5. The same syndrome as in variant 1, but sensitivity in the face is impaired bilaterally.

Occlusive lesions of the vertebral arteries may cause not only retro-olivary infarction, but also infarction in some other portions of the brain stem. Disorder of circulation in the vertebral artery may lead to the hemiunilateral syndrome of the medulla oblongata which is a combination of the medial and lateral syndromes.

The **symptoms of hemispheric infarction.** The *incidence* of hemispheric infarction in the carotid system is essentially higher (3-5 times as much) than the incidence of infarction in the vertebrobasilar system, including the area of the posterior cerebral arteries. As to the territory of the internal carotid, the incidence of infarction is higher in the area of the middle cerebral artery, especially in that of its cortico-subcortical branches. Infarction is found much less often in the area of the anterior cerebral artery.

Infarction in the vertebrobasilar system more commonly affects the brain stem, less often—posterior portions of the hemispheres.

Among the focal symptoms of hemispheric infarction the commonest ones are paresis or paralysis of the contralateral limbs with concomitant central paresis of the facial and hypoglossal nerves, disorders of sensitivity, hemianopsia. When the focus is in the dominant hemisphere, disorders of speech occur (various aphasias) and of other higher cortical functions; dextrohemispheric infarctions cause derangement in the body schema, anosognosia. Blepharospasm is not uncommon in the side of the lesion.

In many patients there is a transient phase of early rise in muscle tone which is often followed by the phase of diaschistic hypotonia, giving way to late spasticity. In some patients early muscle hypertonia immediately leads to persistent spasticity. Muscular dystonia and hormetonic convulsions occur in extensive hemispheric infarction attended with essential cerebral oedema and secondary dysfunction of the brain stem. Early muscular hypotonia in the paretic limbs usually occurs in confined infarction or in severe somatic condition.

The **symptoms of brain-stem infarction. Ischaemic stroke** with localization of the focus of lesion in the area of the brain stem may result in paresis of the limbs along with a nuclear lesion in the craniocerebral nerves (leading to oculomotor disorders, nystagmus, vertigo, dysarthria, dysphagia, disorders of posture, coordination, and vital functions); occasionally these symptoms are combined in a form of alternating syndromes. The commonest complaint is headache, predominantly in the cervico-occipital area. Some patients have not only the brain-stem symptoms, but also the following signs of dyscirculation in the posterior portions of cerebral hemispheres, which are supplied by the posterior cerebral arteries: photopsia, disorder of vision, sometimes in the both eyes, but more

often in the form of hemianopsia; acute onset of the Korsakov syndrome; symptoms of thalamic lesion—impairment of sensitivity, tonic bending of the hand by the 'thalamic' type, hyperkinesis of choreoathetotic nature. When there is a lesion in the oral parts of the brain stem or pons, the patients may have early rise in muscle tone. Early muscular hypertonia is displayed either by a syndrome of relatively persistent decortical or decerebrate rigidity, or by variants of hormetony. When the ischaemic focus becomes more extensive and destroys the structures responsible for adequate muscle tone (alleviating tonogenic structures), development of muscular hypertonia is impossible, and hypotonia or atonia develops instead.

A cerebellar lesion may bring about muscular hypotonia or atonia, but occasionally there are paroxysms of a rise in muscle tone or hormetonic convulsions.

Other manifestations of ischaemic stroke. *Epileptic convulsions* of both focal and generalized nature are rare in the early period of ischaemic stroke; they are somewhat more common in the residual period.

Vomiting occurs seldom and mainly in brain-stem lesion. The *meningeal symptoms* are not typical, but they may occur as a complication of cerebral oedema or in haemorrhagic infarction. Loss of *consciousness* does not occur in most patients with ischaemic stroke, though it may be affected somewhat. More often there are some stupefaction, hypersomnia, and a certain disorientation. A more evident disorder of consciousness including sopor or coma is characteristic of extensive hemispheric infarctions with pronounced cerebral oedema and the secondary brain-stem syndrome. This is seen in occlusion of the intracranial portion of the internal carotid causing dyscommunication of the circle of Willis, or in occlusion of the main trunk of the middle cerebral artery. Acute disorder of consciousness may evolve at the very onset of the stroke, but progressive impairment of consciousness along with development of cerebral oedema and aggravation of the secondary brain-stem syndrome is more typical. Acute disorder of consciousness occurs when there is a growing vertebrobasilar occlusion.

Ischaemia in the mesodiencephalic area brings about some variability of the level of patient's activity: during a short period of time there may be variations including full consciousness, stupefaction, sopor, and a condition close to coma. Transient loss of consciousness in the early period of ischaemic stroke may be concomitant to dyscirculation in the area of the nuclei of the reticular formation, which exert ascending triggering influence on the cortex. This happens in disturbances of circulation in the vertebrobasilar system or in the medial group of the basal branches of the anterior cerebral artery, partially supplying the anterior portions of the hypothalamus.

Vegetative disorders in the early period of ischaemic stroke may be expressed as a complaint of 'being sick', sensation of darkening in the eyes, general weakness; the face may be pale with a cyanotic hue. Body temperature is normal, if there is no some concomitant somatic complication. Hyperthermia occurs only in severe brain-stem stroke or in extensive hemispheric infarction with cerebral oedema and secondary dysfunction of the brain stem and hypothalamus. Arterial pressure is usually either normal or decreased; its reactive increase is noted occasionally in patients with occlusion of the carotid artery in the area of its sinus, as well as with infarction in the brain-stem area. Ischaemic stroke may develop, however, in spite of high arterial pressure and even when there is an additional rise in it. In the circumstances, haemorrhagic infarct may occur along with white one. Pulse, as a rule, is accelerated and weak.

Pathological changes in the heart. Symptoms of *coronary cardiosclerosis* are not uncommon in ischaemic stroke, just as angina pectoris or myocardial infarction in the case history. ECG indicates changes in the myocardium, impairment of intracardiac conduction, insufficiency of coronary circulation; a part of the patients show focal changes in the myocardium as a sequela of cicatricial post-infarction cardiosclerosis. Occasionally disturbances in the rhythm of cardiac contractions are registered, such as extrasystole, ciliary arrhythmia, paroxysmal tachycardia, which presuppose development of cerebrovascular embolism. Apart from cardiac pathology, there is often lower pulsation in the major vessels, in particular the carotid, subclavian, and distal arteries of the limbs. Not uncommonly the walls of the vessels are thickened, there is a persistent asymmetry of arterial pressure, and vascular murmurs are auscultated in some of the patients in the area of the carotid, subclavian, and vertebral arteries. Signs of atherosclerosis may be found by means of the study of the eye fundus. In some patients ischaemic stroke occurs while there is already acute cardiovascular failure or decompensated cardiac function. The post-insult period is difficult. Ischaemic stroke is not infrequently encountered in patients with heart valvular disease or vasculitis.

The **symptoms of thrombosis in cerebral vessels.** These symptoms vary and depend on localization and the size of the focus of softening, as well as on the aetiology of the illness. In thrombosis, focal symptoms develop gradually, consciousness is often retained, and there is the ischaemic status (pallor of the face, stenosis in the arteries of the eye fundus, weak pulse, deterioration in cardiac activity, etc.).

Embolism. Embolism is attended with a sudden momentary loss of consciousness, dizziness, growing mono- or hemiparesis, occasional convulsions, transient meningeal symptoms. The face is usually pale, pulse accelerated and arrhythmic. There are chill, subfe-

brile temperature, widening of the heart boundaries, systolic murmur; arterial pressure is not raised, there may be signs of embolism of the central artery of the retina; infarctions of the kidneys, spleen or lungs sometimes occur as well.

Haemorrhagic infarct. Haemorrhagic infarct is most common when hypertensive disease is combined with atherosclerosis, or when there is cardiogenic or arterio-arterial embolism, or abnormal tortuosity of the carotids. The clinical manifestations are similar to those of white infarct or cerebral haemorrhage. The onset is apoplectiform with arterial pressure often raised.

Two variants of the clinical course of haemorrhagic cerebral infarct are distinguished. The first variant is characterized by an acute onset of stroke with pronounced general cerebral, meningeal and hemispheric focal symptoms and development of the progressive secondary brain-stem syndrome. The second variant is characterized by a 'clear period' at the onset with mildly pronounced general and focal cerebral symptoms, followed usually during the first three days with growing neurological symptoms and deterioration of the patient's status. Diagnosis is based upon the clinical criteria, findings of examination of the cerebrospinal fluid and echoencephalography.

The clinical features of ischaemic stroke are observed in both its thrombotic and non-thrombotic types. It is found to be rather difficult to distinguish them by clinical criteria.

Methods of examination. *Peripheral blood* of patients with ischaemic stroke, especially during the first 24 hours, does not usually show any essential changes. High leucocytosis is revealed rarely, and particularly in infarcts within the brain-stem area or in extensive hemispheric infarcts with a secondary dysfunction of the brain stem. Neutrophilic leucocytosis with a shift in differential blood count is typical of haemorrhagic infarct.

Haemocoagulation values cannot be used for the diagnosis of ischaemic stroke, since there are no established pathognomonic changes. In the main, they show the response of the coagulation and anticoagulation systems to the stroke and almost never reflect the changes in the physicochemical properties of the blood that preceded the stroke and possibly promoted it. In the acute period of ischaemic stroke, hypercoagulability is noted in 25 to 50 per cent of the cases. The rise in the coagulative factors is usually most distinctly pronounced during the first three to five days of the disease and reveals itself as an increase in fibrinogen, prothrombin, tolerance of plasma to heparin, and hypoheparinaemia, while the fibrinolytic activity is either normal or reduced. Not uncommonly in the post-stroke period the phase of blood hypercoagulation is followed by the phase of hypocoagulation which is seen in a sharp fall in fibrinogen, a drop in both the prothrombin index and blood

platelets. Patients with acute cerebral infarction often show an increase in aggregation of blood platelets (Fig. 52); it is maintained for the first two weeks and returns to the normal no sooner than in 30 days of the illness. The highest aggregation of blood platelets is registered during the first three days; it is typical for the first 24 hours to observe a drop in blood platelets and a rise in their adhesive capacity, which is possibly due to their use for intravascular thrombogenesis.

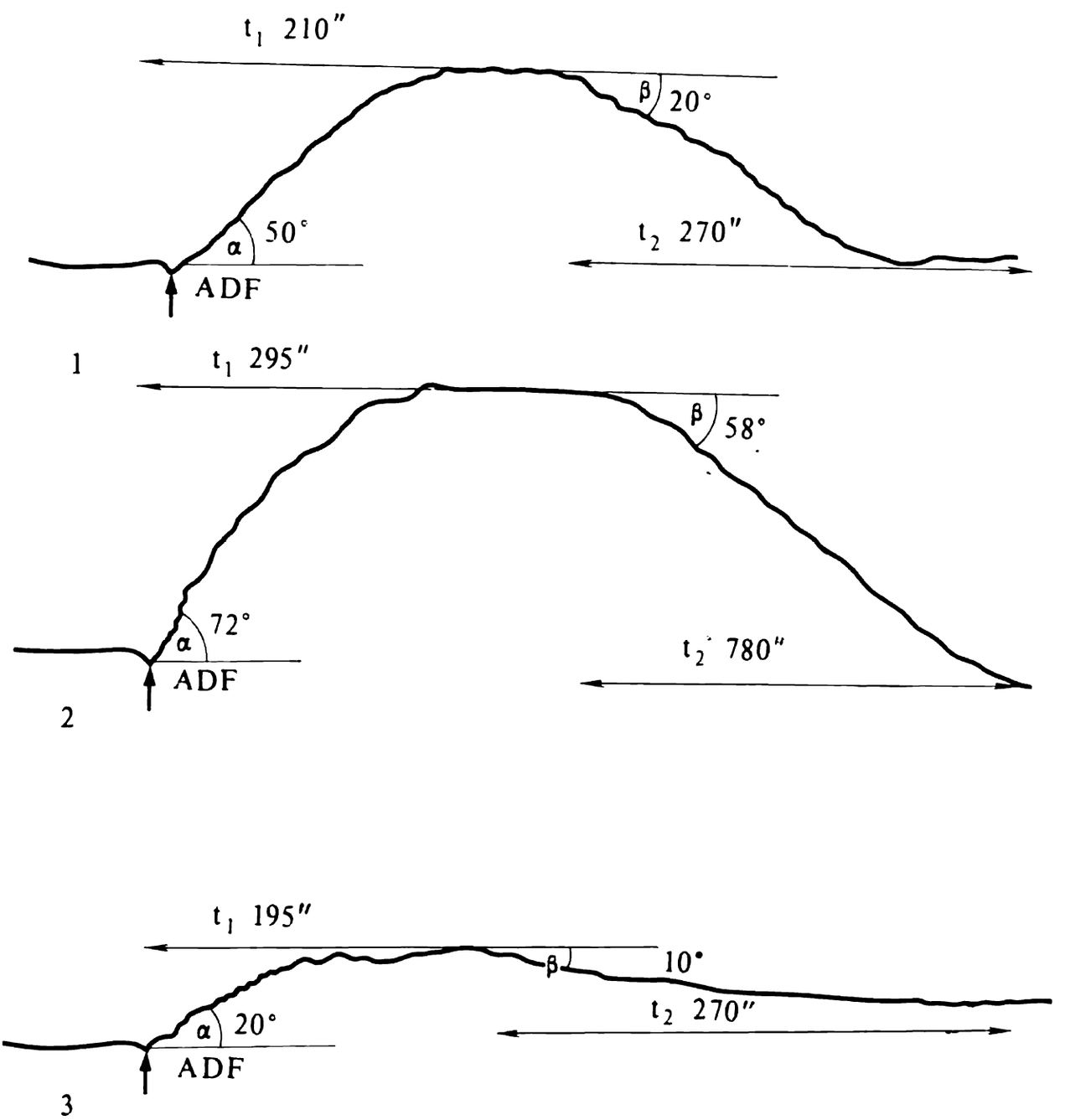


Fig. 52. Aggregatogram of platelets in health and in disease.

1—in health; 2—raised aggregation in a case of ischaemic stroke; α—the angle showing the rate of formation of the thrombocytic aggregates; *3*—decrease in the platelet aggregating capacity; *t*—time of aggregation (in seconds) from the moment of adding the aggregating agent; β—the angle characterizing the rate of dysaggregation; t_2—time of dysaggregation (in seconds). ADF—the moment of administration of the aggregating agent (adenosine diphosphate)

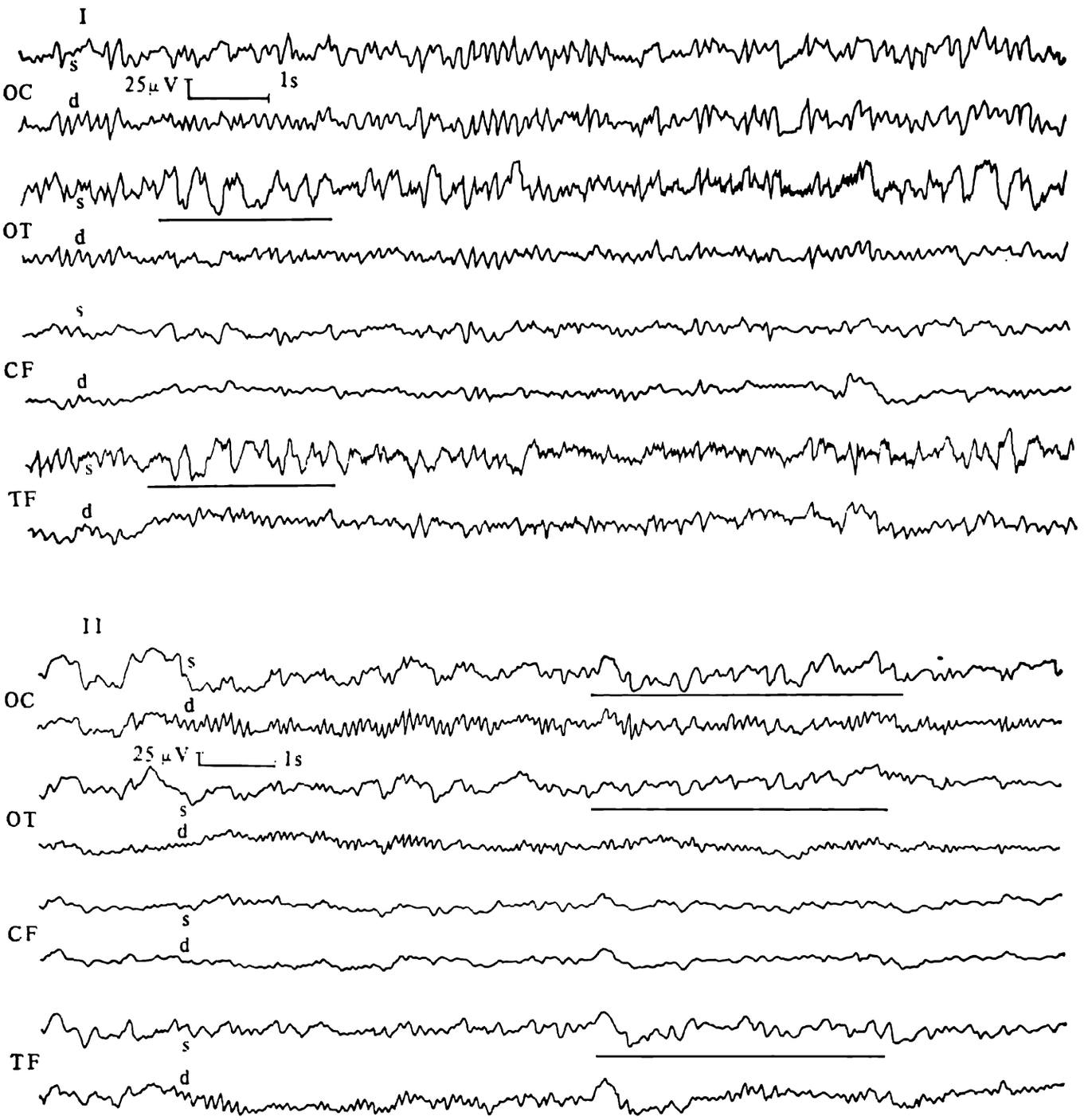
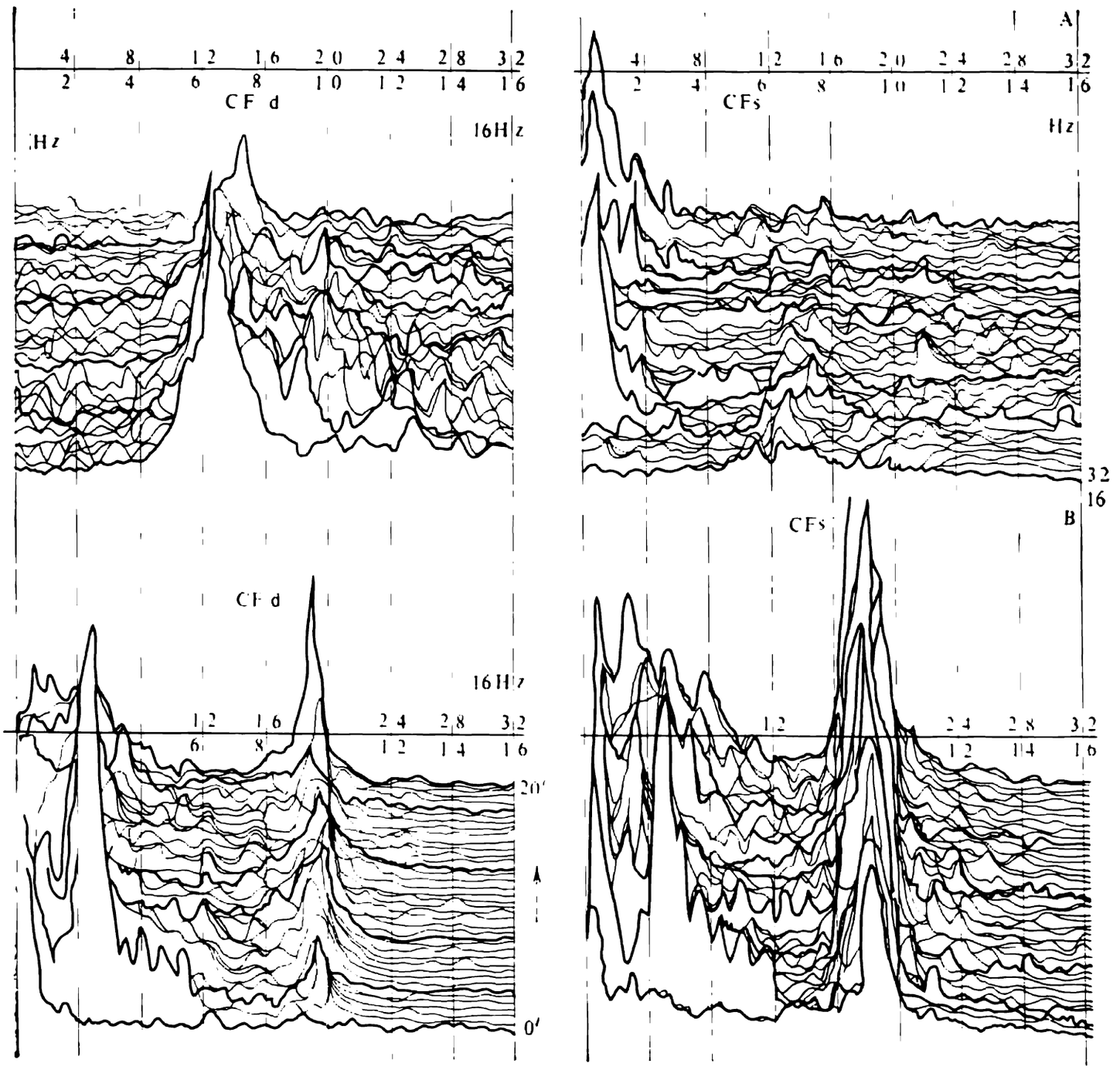


Fig. 53.

I—Electroencephalogram of a patient with stenosis of the left internal carotid artery. Groups of high-amplitude slow waves are registered in the left temporal area. The leads: OC—occipito-central; OT—occipito-temporal; CF—central frontal; TF—temporal frontal; *s*—on the left side; *d*—on the right side. *II*—Electroencephalogram of a patient with occlusion of the left internal carotid artery. Interhemispheric asymmetry is revealed by the prevalence of the abnormal slow waves in the left side, especially in the temporal occipital leads. Designations are the same as in EEG I

The *cerebrospinal fluid* is usually transparent, sometimes a small rise in protein is noted. Xanthochromic or pink colour of the fluid may be seen in both haemorrhagic and mixed infarctions. The number of blood formed elements increases in extensive cerebral infarcts, neighbouring the cerebrospinal fluid-containing space and causing specific response in the cerebral meninges and ventricular ependyma.

III



III—compressed spectrogram of an electroencephalogram recorded for 20 minutes in a case of infarction in the left hemisphere of the brain:
A—the first 24 hours of stroke; pronounced interhemispherical asymmetry of the total power of the EEG with a depression in the affected hemisphere due to decreased alpha peak; delta activity is increased;
B—20th day of stroke: a decrease of the total power of the EEG and an increase of the alpha peak in the affected hemisphere on the background of a regress of cerebral symptoms; delta activity is retained in both hemispheres

Electroencephalography (Figs. 53 and 54) in cases of cerebral infarction often elicits interhemispheric asymmetry and a focus of abnormal activity. *Rheoencephalography* (Figs. 55 and 56) allows assessing the interhemispheric asymmetry by the degree of diminution and flattening of the pulse waves in the affected side as well as the change of blood volume in the pertinent vascular areas.

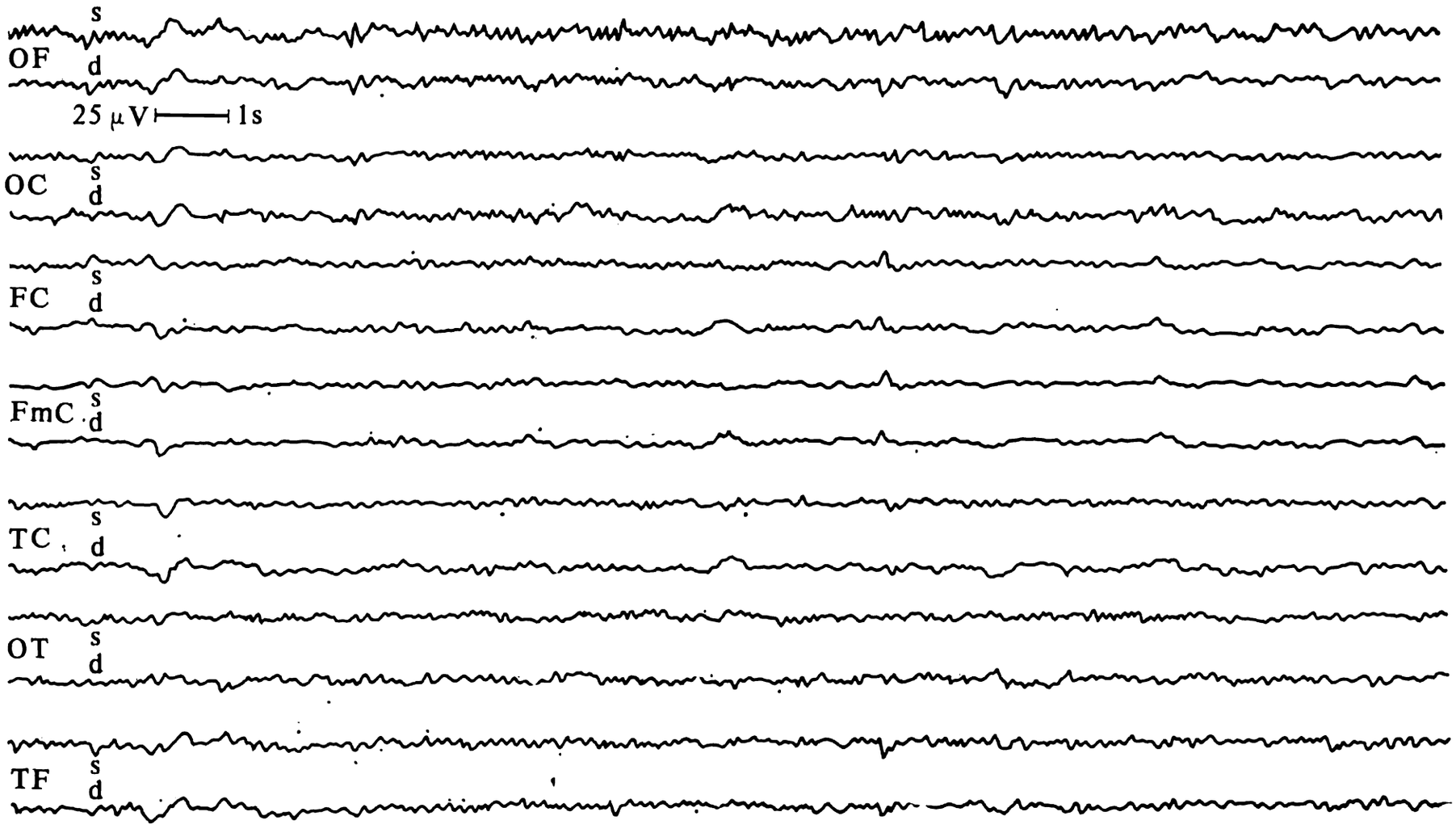


Fig. 54. Electroencephalogram of a patient with vertebro-basilar insufficiency. EEG of a desynchronous type is registered: the alpha waves are absent, beta activity is heightened, zonal distinctions are effaced, the amplitudes of the fluctuation of biopotentials are decreased. The leads: OF—occipito-frontal; OC—occipito-central; FC—frontal central; FmC—medial frontal central; TC—temporal central; OT—occipito-temporal; TF—temporal frontal; *s*—on the left side; *d*—on the right side

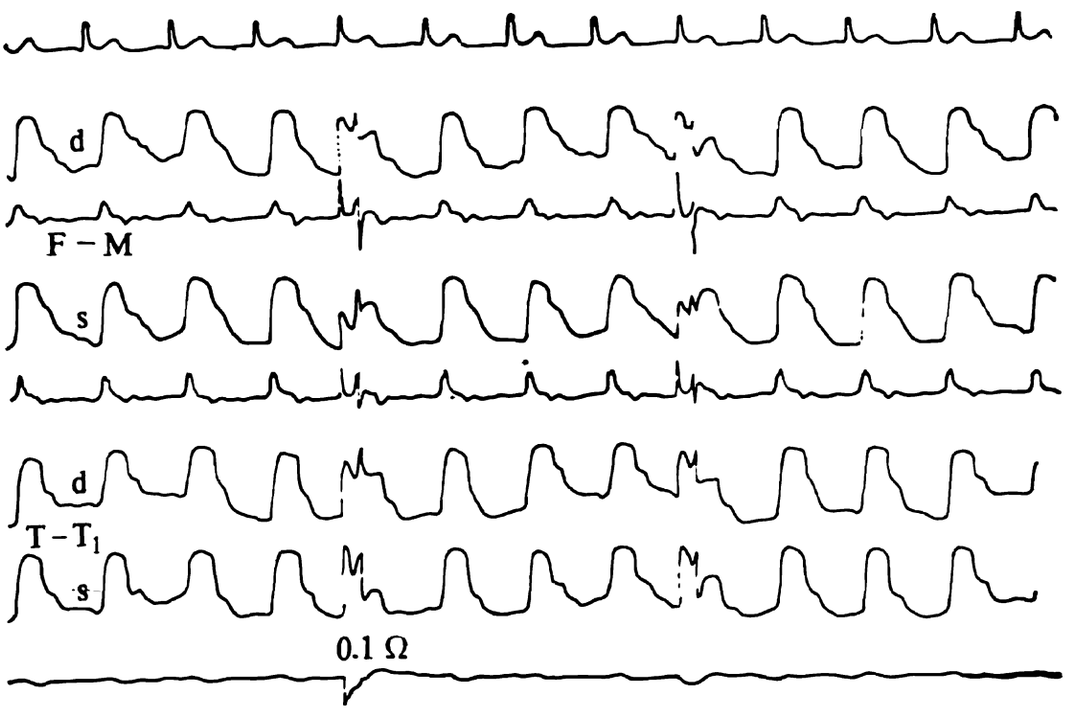


Fig. 55. Rheoencephalogram of a patient with cerebral infarct in the territory of the right internal carotid artery. Interhemispheric asymmetry is revealed by lower pulse volume in the right hemisphere. Compensatory increase of the blood flow may be seen in the left hemisphere and the territory of the right external carotid artery. F-M—areas of the internal carotid arteries, $T-T_1$—areas of external carotid arteries.

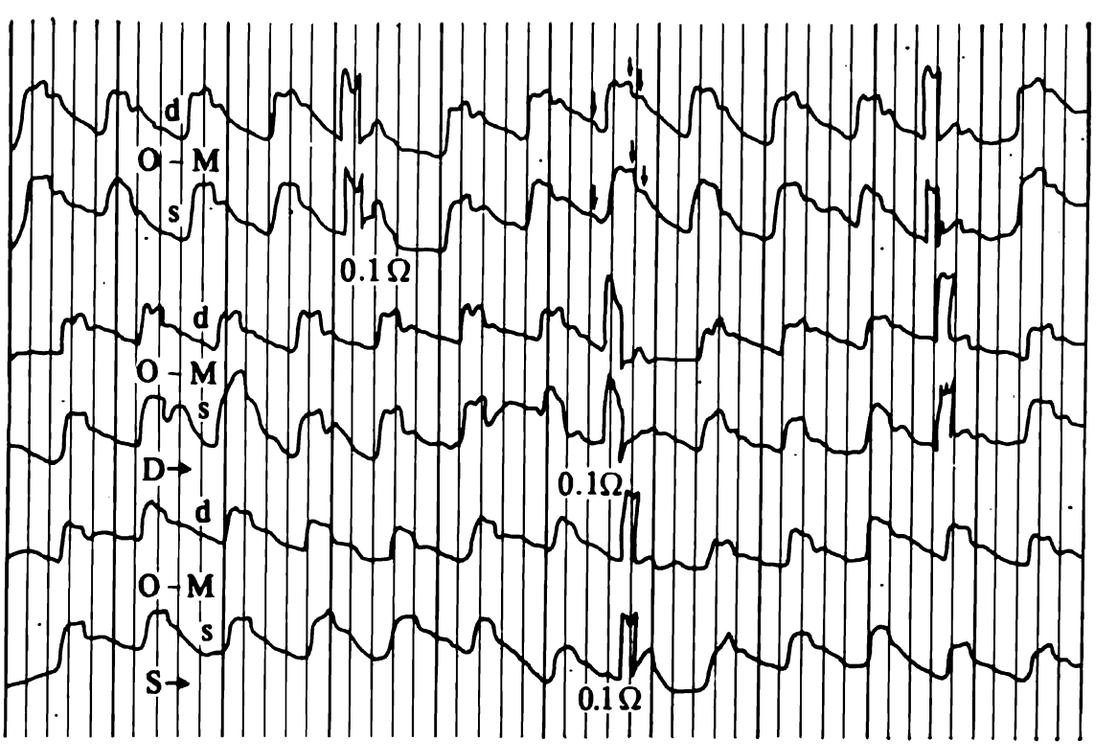


Fig. 56. Rheoencephalogram of a patient with cervical osteochondrosis, early signs of atherosclerosis and dyscirculation in the vertebrobasilar vascular system. Blood volume in the areas of the vertebrobasilar system is decreased in the both sides; there are signs of angiodystonia and impediment in the venous outflow. There is a gross vertebrogenic influence from both sides which is indicated by lower amplitude of the pulse waves when the head is turned aside (d→, s→).

Echoencephalography (Fig. 57) in case of ischaemic infarction usually does not show any shift of the M-echo, except in extensive infarction and cerebral oedema when some small shifts may occur (2-4 mm), which disappear later.

Angiography (Figs. 58*A* and 59*A*) of cerebral vessels shows the presence of an occlusive process, if any, in the extra- and intracranial vessels of the brain, active pathways of collateral circulation, abnormal tortuosity and kinking of the arteries, congenital anomalies of cerebral vessels. *Doppler principle flowmetry* (Figs. 58*B* and 59*B*) permits finding occlusion and pronounced stenosis in the carotid and vertebral arteries.

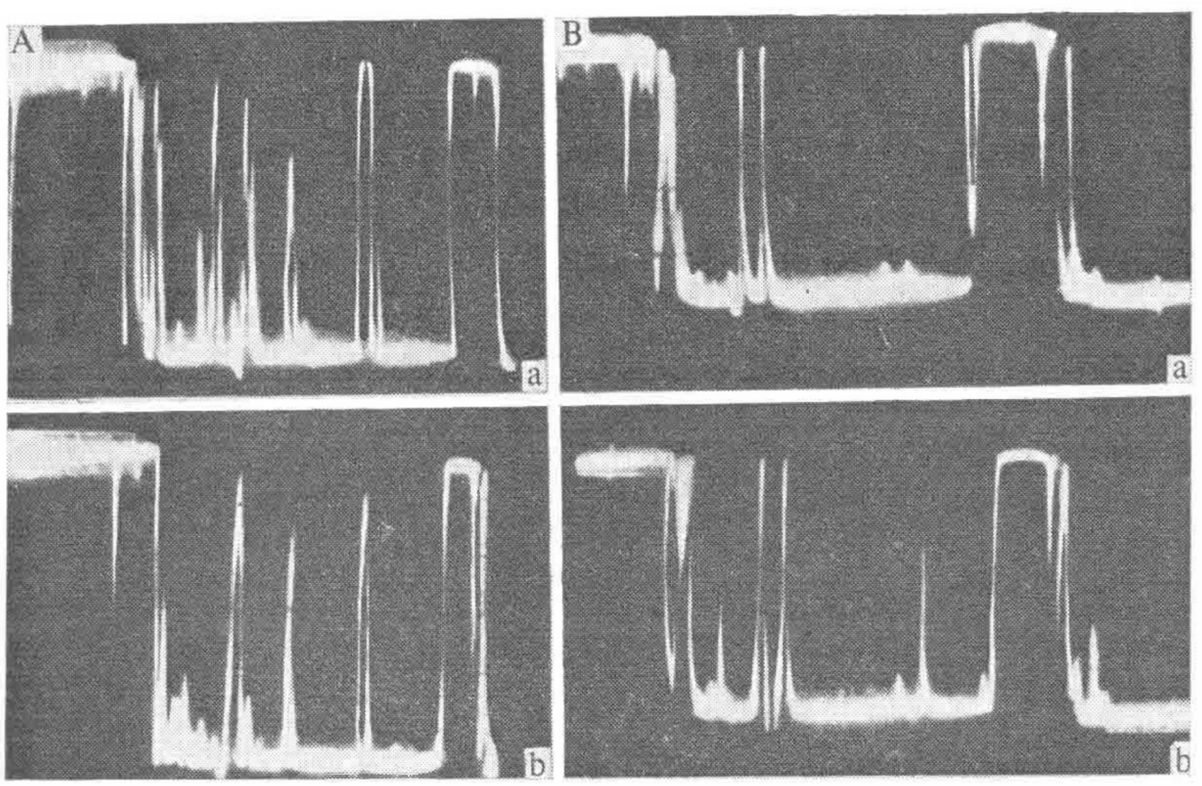


Fig. 57. Echoencephalograms.

A—echoencephalogram of a patient with haemorrhagic infarct, cerebral oedema is more pronounced in the left hemisphere; *a*—the sensor is on the left side, *b*—the sensor is on the right side.

B—echoencephalogram of an atherosclerosis patient with insufficiency of cerebral circulation in the vertebrobasilar vascular system; *M*—echo consists of two peaks with a 6 mm span between them; the number of additional peaks is small. Conclusion: intracerebral hypertension.

a—the sensor is on the left side, *b*—the sensor is on the right side

Computer tomography makes it possible to find in cerebral infarction (Fig. 60) some areas of decreased density of the parenchyma in the relevant zones, unlike those of increased density in haemorrhages (Fig. 61). *Electromyography* (Fig. 62) allows the degree of clinical and subclinical disorders in muscle tone to be estimated and their pyramidal and extrapyramidal forms differentiated. *Thermography* (Fig. 63) is applied to diagnose an occlusive process in the internal carotid artery. *Scanning* of the brain (Fig. 64) shows changes of radioactivity in the focal area of infarction.

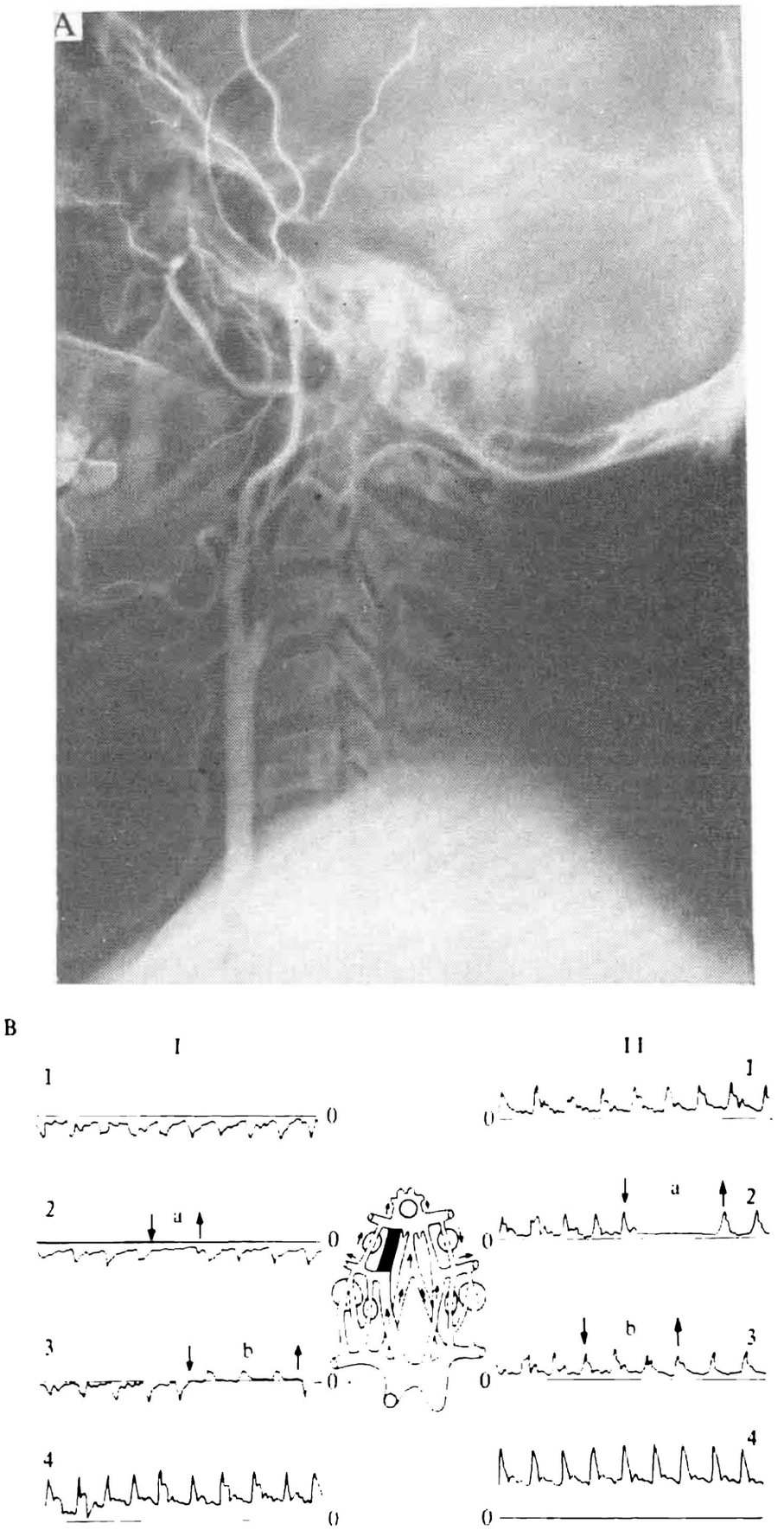
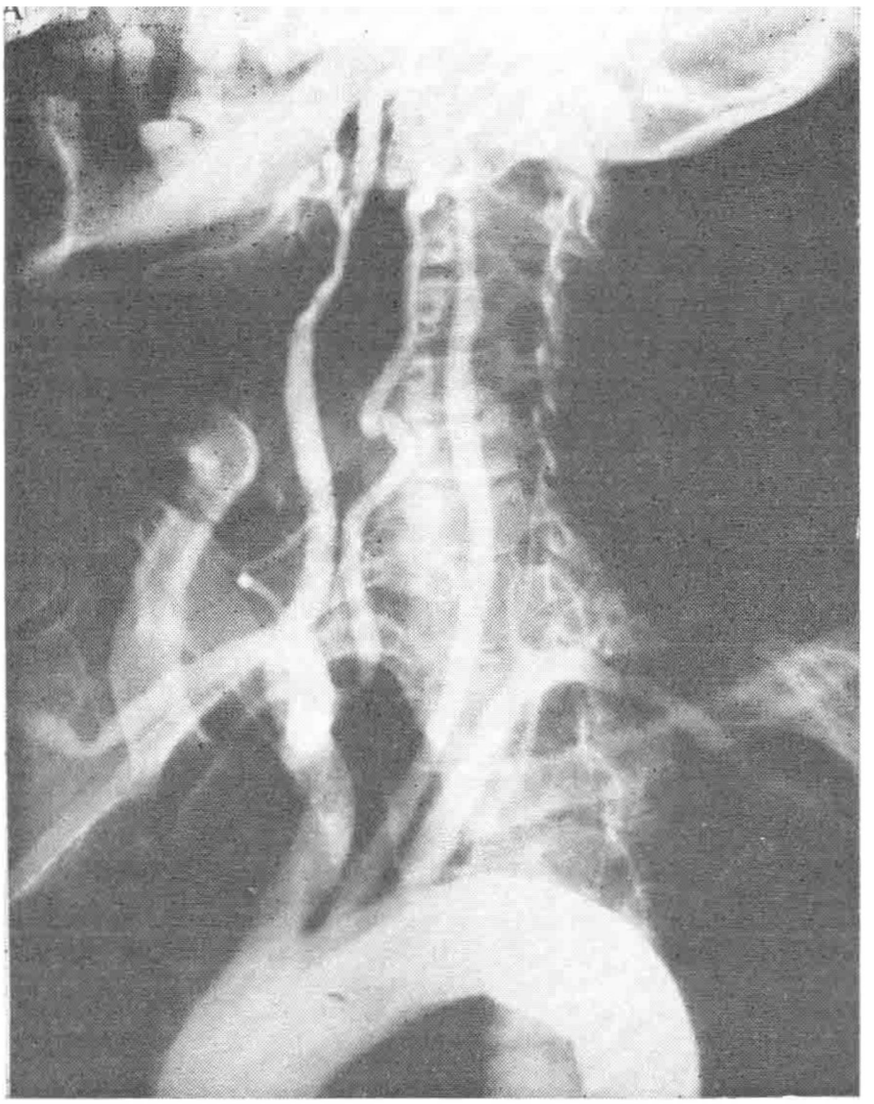


Fig. 58. *A*—angiogram in occlusion of the right internal carotid; *B*—ultrasound dopplerograms and a diagram of the blood supply to the brain in occlusion of the right internal carotid; retrogressive blood flow in the supratrochlear artery in the side of occlusion of the internal carotid:

1 ... *3*—supratrochlear artery: *a*—compression of the common carotid in the homolateral side; *b*—compression of branches of the external carotid; *4*—common carotid; *I*—right side; *II*—left side



B

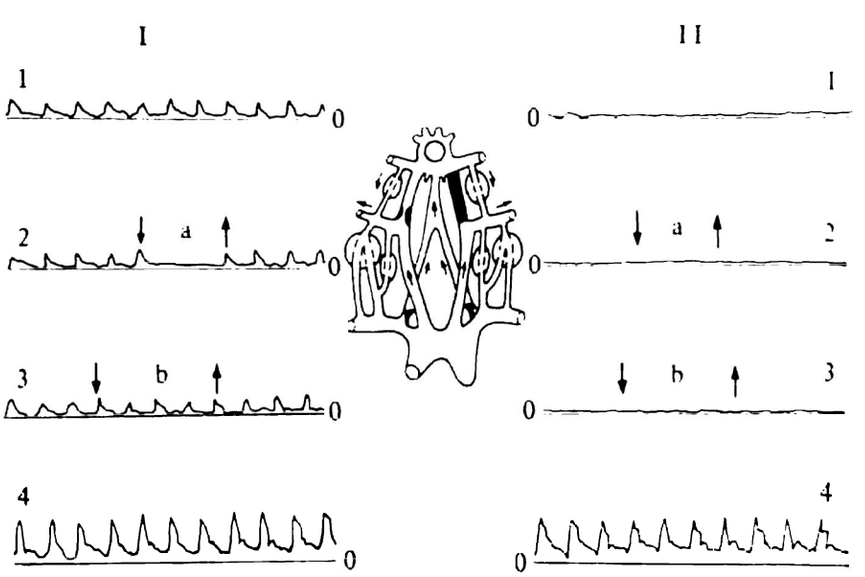
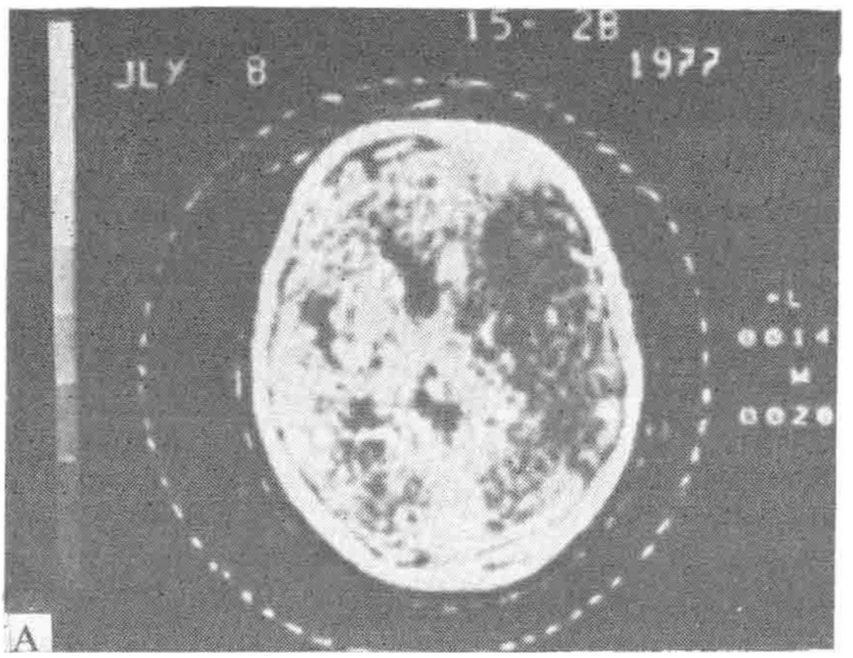


Fig. 59. *A*—Aortogram in case of occlusion in the left internal carotid, stenosis in the right carotid, occlusion in the left vertebral artery, stenosis and tortuosity of the right vertebral carotid;
B—ultrasound dopplerograms and a diagram of the blood supply to the brain in case of occlusion in the left vertebral artery, stenosis in the right vertebral artery and occlusion in the left internal carotids:

1,2—supratrochlear artery; *3*—vertebral artery; *a,b*—compression of the common carotid; *4*—common carotid; *I*—right side; *II*—left side



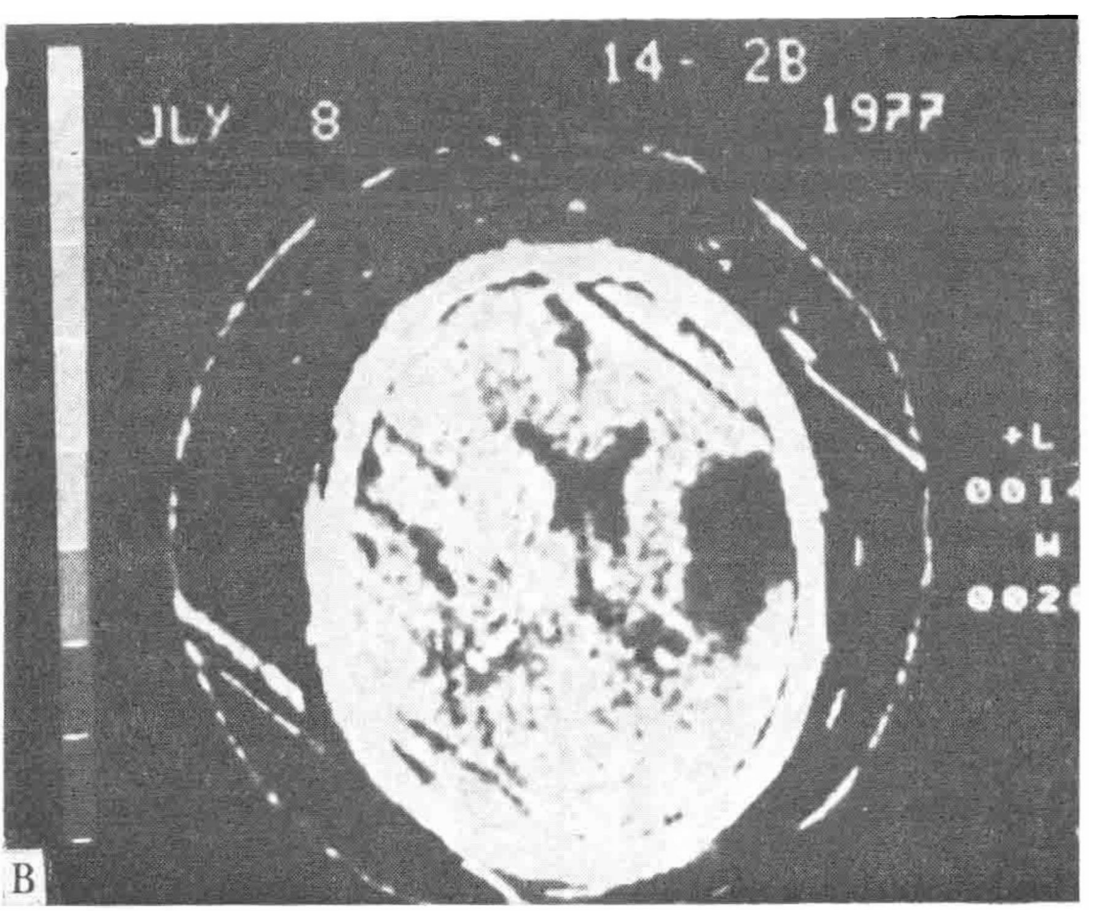


Fig. 60. Computer tomograms of patients with cerebral infarct.

A—an area of lower density (of dark colour) with indistinct contours is seen, as well as dislocation of the ventricular system to the left. *B*—the area of infarct—a site of considerably reduced density in the right hemisphere with distinct boundaries; the lateral ventricles are unchanged

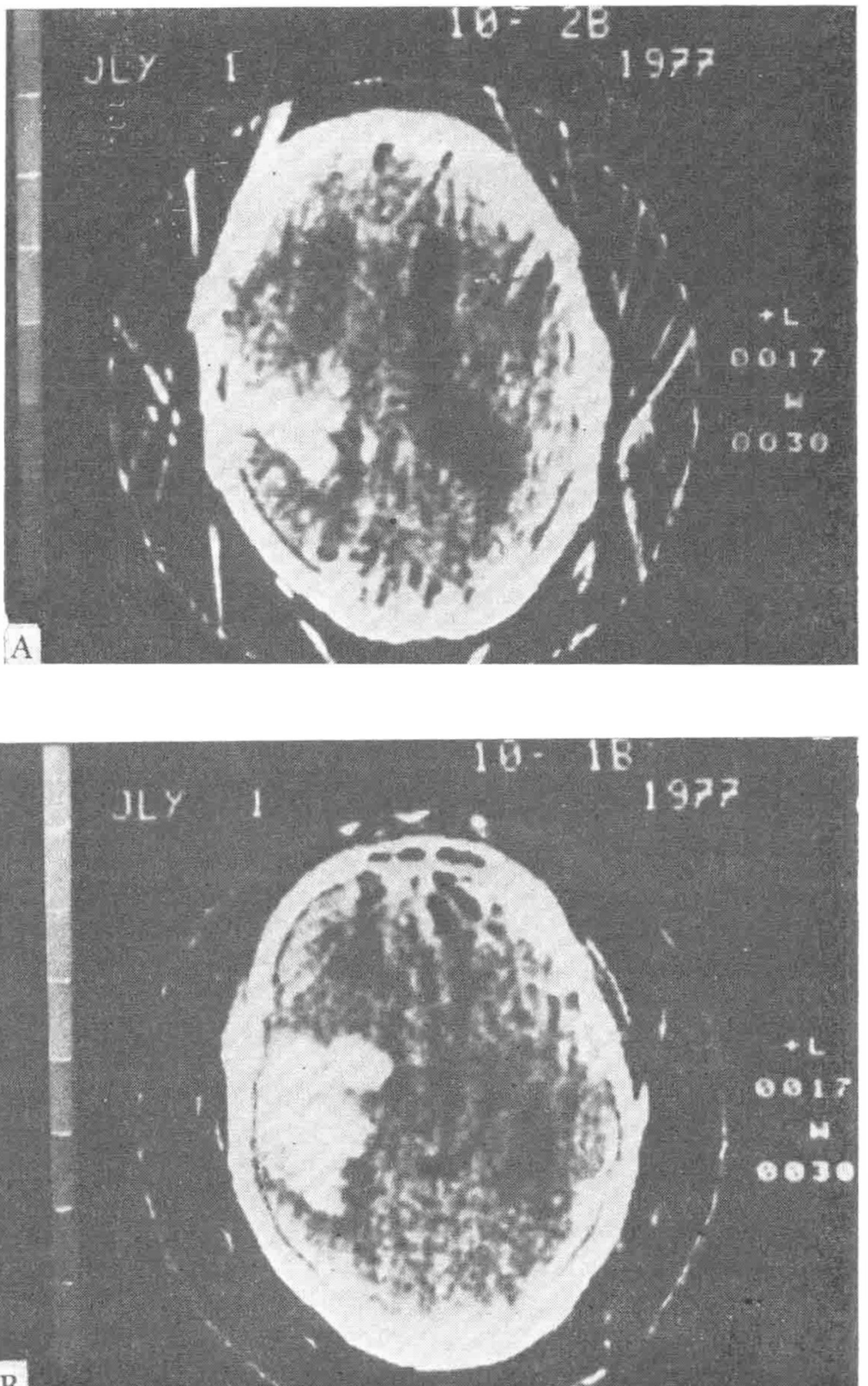


Fig. 61. Computer tomograms of a patient with cerebral haemorrhage. The sections show a site of greater density in the left parietotemporal area white-coloured) with distinct rugged contour; the lateral ventricle is expanded (*A*), the third ventricle is displaced contralaterally (*B*).

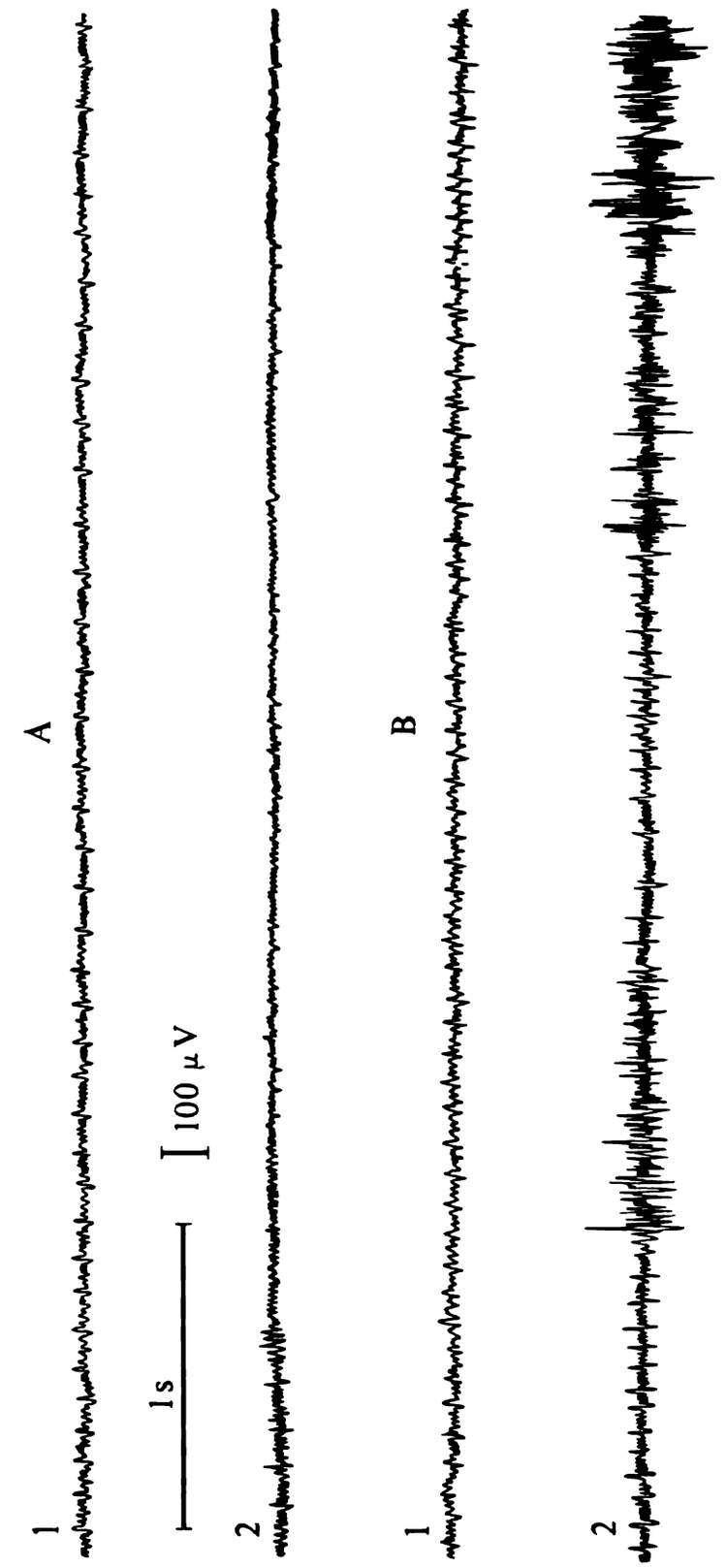


Fig. 62. Electromyogram of a patient with right-sided hemiparesis which followed a disorder of cerebral circulation.

A—rhythmical bioelectrical activity registered in rest in the extensor of the hand; *B*—hyperactivity in the hand flexor at the restoration stage. *1*—m. extensor carpi dexter; *2*—m. flexor carpi radialis dexter.

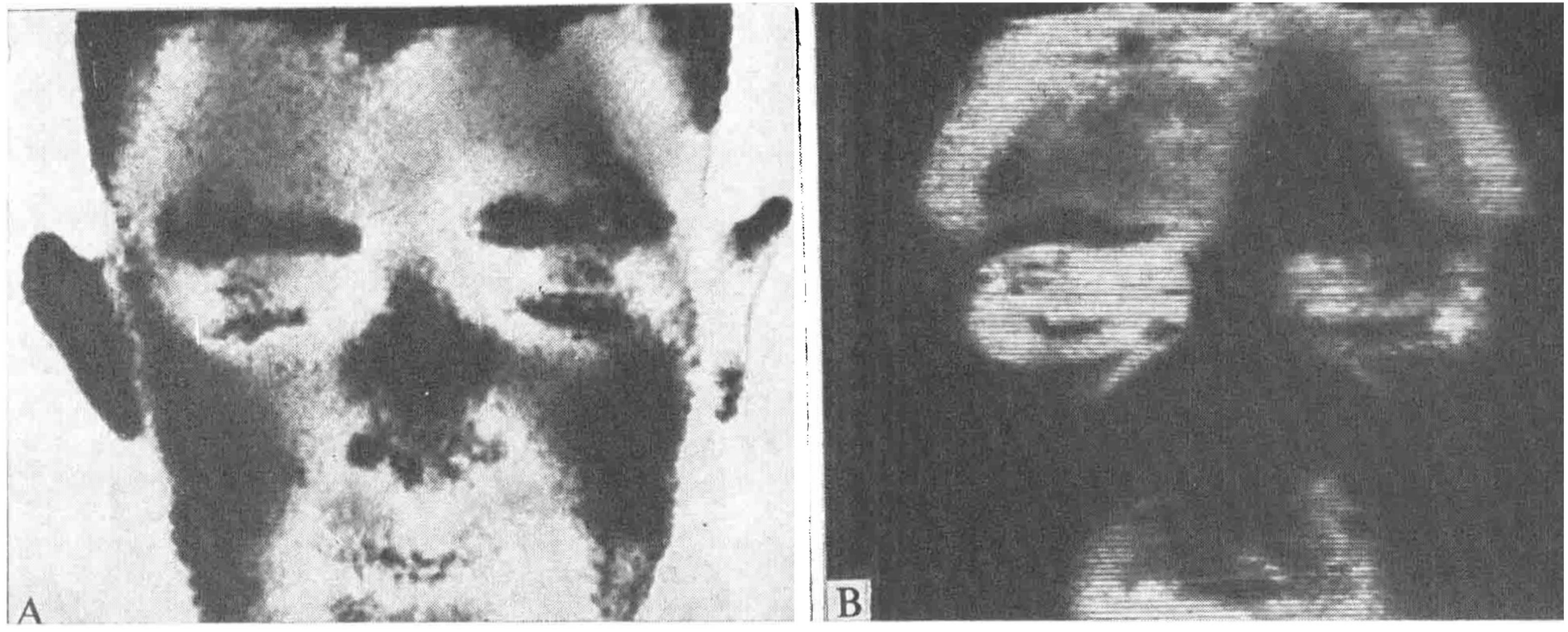


Fig. 63. Thermograms.
A—of a healthy person; *B*—of a patient with occlusion of the internal carotid artery.

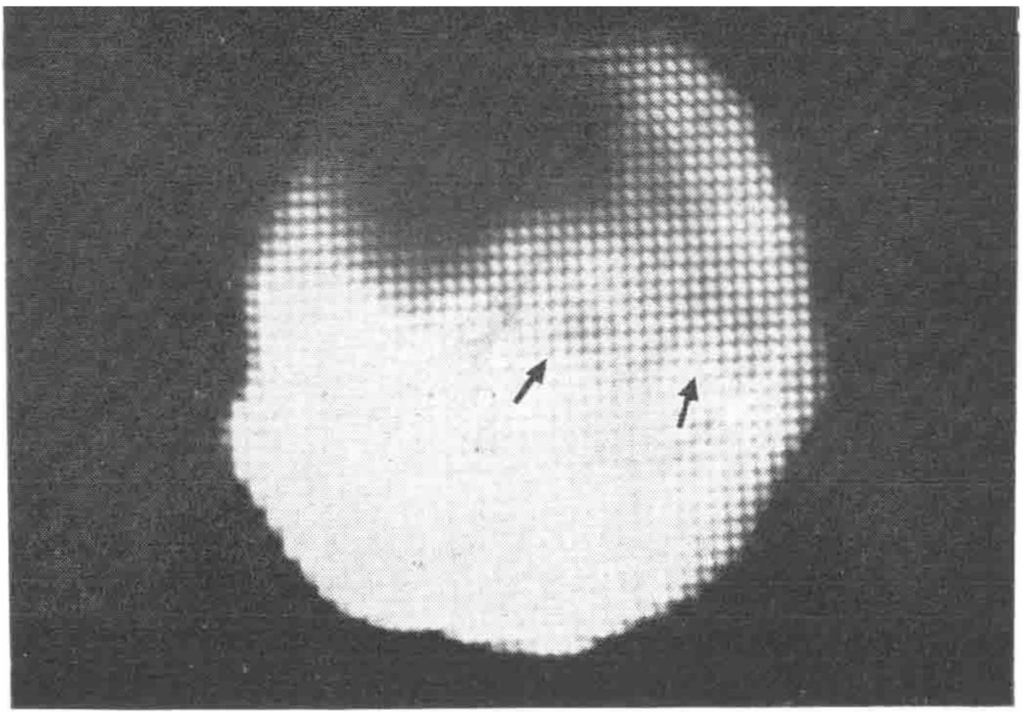


Fig. 64. Scintigram. A case of thrombosis in the left middle cerebral artery. Considerable homogeneous intensive accumulation of the isotope (technetium 99 M, pertechnetate) registered in the posterior of the hemisphere (shown by the arrows).

4.10. Psychic Disorders in Cerebral Stroke

Psychic disorders in the early period of stroke are displayed mainly by various syndromes of impairment of consciousness. Most often there are stupefaction, sopor, coma; not infrequently twilight, amentive, delirious, oneiric, or mixed forms of clouding of consciousness known as 'confused states'. Beyond the periods of disturbed consciousness, various reversible psychic changes may be observed, such as asthenic, apathetic states or depression and anxiety; there may be also hallucinosis, acute delirium; euphoric, pseudoparalytic or the Korsakov syndromes. Psychic changes are considerably more common when the right hemisphere is affected and the concomitants are, as a rule, anosognosia and deranged body schema.

The residual period is characterized by prolonged or chronic asthenic state or persistent postapoplectic dementia. The following forms of dementia are distinguished: simple lacunar, pseudoparalytic, Korsakov's and complex vascular-atrophic, i.e. the same ones which are found in atherosclerosis without stroke. The first two forms of dementia occur more often after the stroke, their manifestations are relatively more pronounced and they are commonly seen in combination with focal signs of cerebral lesion. This may

provide a background for the above-mentioned transient psychic disorders; as for hereditary tainted or psychopathic individuals with mild organic deterioration, they may have prolonged affective, paranoiac or hallucinatory-delirious psychoses. Such a variety of psychic disorders is due to the character of the background vascular process, localization and size of the focus, and individual traits of a patient.

4.11. Diagnosis and Differential Diagnosis

In the diagnosis of stroke, the following should be taken into account: (1) the data in the case history; (2) the clinical picture; (3) findings of examination of the cerebrospinal fluid; (4) results of examination of the eye fundus; (5) electrocardiography; (6) rheoencephalography; (7) echoencephalography; (8) electroencephalography; (9) laboratory tests (blood coagulability, the content of prothrombin, fibrinogen, sugar, urea in the blood, etc.); (10) radiographic examinations (craniography, angiography).

The differential diagnosis of haemorrhagic and ischaemic strokes is shown in Table 1. Stroke should be distinguished from apoplectiform diseases or states. These are: (1) the apoplectiform syndrome in myocardial infarction; (2) apoplectiform development of a cerebral tumour, i.e. haemorrhage into the tumour (in haemangioma), into the brain stem (in spongioblastoma) and around the tumour; (3) craniocerebral trauma in the acute period (head contusion in the case history, objective signs of damage to the skin and bones of the cranium); (4) alcoholic intoxication (alcoholic breath disorients if the stroke develops after alcohol intake); (5) uraemia (anuria, a special type of countenance of the patient, changes in the urine, azotaemia); (6) progressive paralysis; (7) poisoning with carbon monoxide; (8) hyper- or hypoglycaemic coma; (9) haemorrhagic meningoencephalitis (temperature, vomiting, excitement, the cerebrospinal fluid tinged with blood, encephalytic symptoms); (10) epilepsy.

When stroke is differentiated from *alcoholic coma*, it is necessary to consider symptoms of alcoholic intoxication, such as alcoholic odour of the exhaled air and vomit, excitement at the onset of coma, occasionally epileptiform fits; hyperaemia of the conjunctivae and sclerae; pulse is first tense, then soft; normal arterial pressure, dull heart sounds; hyperaemia and cyanosis in the face, acrocyanosis; cold, damp skin; muscle hypotonia, decreased pupillary and tendon reflexes; hepatomegalia. There are no signs of a focal cerebral lesion.

Primary disturbances of cerebral circulation should be differen-

Table 1.

Differential Diagnostic Signs of Haemorrhagic and Ischaemic Stroke

Signs	Haemorrhagic stroke	Ischaemic stroke		
		thrombosis	embolism	non-thrombotic stroke
Age	45-60 years	More often over 60 years	Young age, more often 20-40 years	Over 60-70 years
Previous cerebral or cardiovascular disorders	Hypertensive cerebral crises, signs of a cerebral aneurysm	Recurrent transient disorders of cerebral circulation	Heart diseases	Recurrent transient disorders of cerebral circulation, myocardial infarction
Prodromes	Flushes to the face, headache, erythropsia	Dizziness, transient impairment of consciousness (semisyncope), darkening before the eyes	Absent	Absent
Development	Sudden, rapid	Gradual	Sudden	Sudden
Onset	During the day-time, after physical exertion, occasionally after emotional excitation, very seldom in sleep	During night-time, before dawn, some hours after a psychic trauma	Commonly in the day-time, often after physical exertion or excitement	More often in the day-time after physical exertion or a sharp drop in arterial pressure, weakening of cardiac activity
State of consciousness	From stupefaction to coma for several days	Retained consciousness or stupefaction, less often sopor or coma	Short-term loss of consciousness	Short-term loss of consciousness, sometimes stupefaction, sopor
The face	Hyperaemia	Pallor	Pallor	Pallor
The pupils	Dilatated (more on the side of lesion), less often narrowed	More commonly narrowed	Moderately dilatated	More commonly narrowed

Signs	Haemorrhagic stroke	Ischaemic stroke		
		thrombosis	embolism	non-thrombotic stroke
'Floating' movement of the eye-balls	Pronounced in abundant haemorrhage	Pronounced in occlusion of the basilar artery	Absent	Pronounced in extensive cerebral infarctions
Hormetony	In haemorrhage into the ventricles, abundant parenchymatous haemorrhage	Absent (but may occur in extensive cerebral infarction)	Absent	Absent
Epileptic convulsions	In subarachnoid haemorrhage	Not typical	May occur	Absent
Meningeal symptoms	Most acutely pronounced in subarachnoid haemorrhage	Usually absent	Occur occasionally; pronounced indistinctly	Usually absent
Abnormal reflexes	Bilateral in ventricular and subarachnoid haemorrhages	Contralateral	Contralateral	Contralateral
Development of focal symptoms	Rapid development of hemiplegia, decrease in reflexes and muscle tone	Gradual development of hemiplegia	Sudden onset of mono-, less often hemiparesis	Rapid development of hemiplegia
Distal symptoms (in hemispherical stroke)	Occasionally brainstem symptoms	Not pronounced	Absent	Occasionally brainstem symptoms
Respiration	Stertorous, gurgling	Weakened, decelerated	Arrhythmic, not uncommonly accelerated	Weakened, slow, sometimes of the Cheyne-Stokes type
Pulse	Tense, slow	Weak	Arrhythmic, rapid	Weak, arrhythmic

Signs	Haemorrhagic stroke	Ischaemic stroke		
		thrombosis	embolism	non-thrombotic stroke
Arterial pressure	Almost always increased	Normal or decreased, occasionally increased	Normal	Normal or decreased, occasionally increased
Heart	Left ventricular hypertrophy	Atherosclerotic myocardiosclerosis	Valvular heart diseases. Endocarditis. Cardiosclerosis. Atrial fibrillation	Cardiosclerosis, chronic coronary insufficiency
Temperature	Elevated in abundant haemorrhage, parenchymatous-ventricular haemorrhages	Sometimes low	Normal. Elevated in endocarditis	Sometimes elevated
The eye fundus	Haemorrhages in the eye fundus, hypertensive retinopathy with oedema and haemorrhages	Commonly sclerosis and stenosis of the retinal vessels	No change. Occasionally embolism of the central artery of the retina	Stenosis of the vessels of the retina
Blood	Leucocytosis, neutrophil shift, neutrophil and lymphocyte ratio raised, adhesion and aggregation of blood platelets decreased	Increased adhesion and aggregation of blood platelets	Occasionally leucocytosis, shift of the blood count to the left, increased ESR	Sometimes increased adhesion and aggregation of blood platelets
Urine	Traces of protein, sometimes presence of sugar	No change	Increased count of leucocytes	Sometimes traces of protein

Signs	Haemorrhagic stroke	Ischaemic stroke		
		thrombosis	embolism	non-thrombotic stroke
Cerebrospinal fluid	Tinged with blood or xanthochromic, normal when the focus is limited. Elevated pressure	Transparent, insignificant pleocytosis with increased protein content, xanthochromic in mixed infarction	Transparent or xanthochromic, occasionally increased cytosis and protein content	Transparent. Normal or mild pleocytosis, increased protein content. Occasionally elevated pressure
Echoencephalography	M-echo shift	Symmetrical location of M-echo. Possible dislocation of M-echo in extensive infarction	Symmetric location of M-echo	Symmetric location of M-echo
Electroencephalography	Gross diffuse changes in cerebral biopotentials, occasionally with interhemispheric asymmetry	Interhemispheric asymmetry, a focus of abnormal activity	Mild local changes in cerebral biopotentials	Interhemispheric asymmetry, a focus of abnormal activity
Angiography	Dislocation of intracerebral vessels, 'vessel-free' area	Occlusion of extra- or intracranial vessels	Unfilled vascular network in the area of the vessel affected with embolism	Stenosis, abnormal tortuosity of an extra- or intracranial vessel, occasionally vessel spasm
Computer tomography	Light focus of haemorrhage	Dark area of infarction	Dark or motley area of infarction	Dark area of infarction

tiated from apoplectiform coma, occurring in *myocardial infarction*. Initially there are pain in the heart area, dizziness, 'fogged' vision, vomiting, pallor, profuse sweating, weakness, unsteady gait, syncope, collapse, later—disorder of consciousness. The following features are also noted: a sharp decrease in arterial pressure, accelerated (or decelerated in an atrioventricular block), weak and arrhythmic pulse, extrasystole, cardiac fibrillation, dyspnoea, cyanosis in the face and hands. Oneiric states or epileptic convulsions are possible. The acrospastic reflex sometimes appears (disappearance of pulse in the arteries of the limbs), abdominal and renal symptoms. There is hyperalgesia in the area of the heart, left scapula, hand. ECG reveals signs typical of myocardial infarction.

Differential diagnosis between disturbances of cerebral circulation and phenomena of *extrarenal azotaemia* or *uraemic coma* is grounded on the following: in a truly uraemic condition consciousness may be impaired not so deeply as in an apoplectic coma. Extrarenal azotaemia in cerebral stroke is displayed by lower values of non-protein nitrogen than in truly uraemic coma. Unlike apoplectic coma, uraemic coma evolves gradually. Prior to coma there are general weakness, undue fatigability, indifference to other people, impairment of the rhythm of sleep (sleepiness in the day and insomnia at night). The basic clinical features of uraemic coma are as follows: ammoniacal breath, puffy face, pale yellowish colour of the skin, dryness of skin and mucous membranes, scratches on the skin, haemorrhagic phenomena, fascicular muscular twitching, raised arterial pressure. There are often disorders of respiration rhythm (of Cheyne-Stokes or Kussmaul type). Local symptoms are not observed in the neurological status. Sometimes attacks of psychomotor excitement occur with visual or auditory hallucinations. Blood tests reveal anaemia with low count of erythrocytes (down to 1 000 000-2 000 000) and low haemoglobin (down to 30-50 g/l, i.e. 3-5 g/100 ml), thrombocytopenia and acute leucocytosis (up to 15 000-30 000), raised contents of urea, creatinine, indican, potassium, non-protein nitrogen. Metabolic acidosis, hyponatraemia, hypocalcaemia, hyperkalaemia are observed. Urine contains much protein and erythrocytes, sanguineous detritus, myoglobin.

The signs of *hepatic coma* evolve gradually and are characterized by symptoms of developing intoxication. Typical is appearance of 'fluttering' tremor in the muscles of the arms and legs, less often in the face. It is especially noticeable when the arms are stretched out, hands put down and fingers spread wide. There are headaches, apathy, hypersomnia in the day, insomnia at night, general weakness, fetor hepaticus, dyspeptic phenomena: bitter taste, loss of taste and appetite. Then there are disorientation, confusion, delirious utterance; attacks of psychomotor excitement and epileptic

convulsions are possible. The tendon reflexes are increased; foot clonus, bilateral Babinski's reflex, meningeal symptoms are present. The body temperature is elevated. The skin is icteric, pale yellow, dry, cold, there are subcutaneous haemorrhages, small red-coloured 'stars' on the skin. The mucous membranes are pale yellow, the sclerae are icteric; there are haemorrhages into the mucous membranes, bleeding from the gums, stomach and intestine, and uterus. Pulse is rapid, arrhythmic; arterial hypotension. When coma becomes deeper, the tendon reflexes disappear, pupils dilatate and are immobile, attacks of psychomotor excitement cease. Singular or serial epileptic fits may occur, or convulsive contractions of some of the muscle groups. Direct bilirubin test shows its elevated content in the blood. The results of the liver functional test become sharply positive. Urine acquires dark-yellow tinge, it contains protein, bilirubin, urobilin, bile acids. Faeces may be discoloured; stercobilin test is positive.

Diabetic hyperketonaemic coma in case of diabetes mellitus develops gradually: appetite decreases, nausea and sometimes vomiting appear, the patients complain of dry mouth, thirst, frequent urination, general weakness, sleepiness, sometimes pains in the abdomen. Arterial pressure drops, pulse becomes rapid. Acetonic odour appears in breathing. Skin and mucous membranes become dry and dehydrated. Blood contains more sugar, ketonic bodies, less sodium; pH goes down (acidosis), neutrophil leucocytosis appears with a shift to the left, ESR goes up. Urine sugar content increases, and acetone and sometimes protein appear. The patient's condition progressively deteriorates, respiration is deep, noisy, consciousness is impaired, the face features become sharp, the eyeballs become soft to the touch. Muscle tone, tendon and periosteum reflexes, arterial pressure decrease, and pulse becomes rapid.

Unlike more common classic diabetical coma, *hyperosmolar non-acidotic diabetic coma* is characterized by a number of signs: (1) diabetes is often either unrecognized until coma or it takes a milder course; (2) it is predominantly found in elderly persons; (3) precipitation factors in 60 per cent of the cases are inflammatory or other diseases, or medical treatment with a dehydrating effect; (4) disorders develop gradually, sometimes in a matter of several days; (5) hyperglycaemia, glucosuria without ketoacidosis, hyperosmolarity in cerebrospinal fluid, blood, and urine, not uncommonly hypernatraemia, raised level of urea in blood, hypokalaemia, and leucocytosis; (6) consciousness is first relatively clear in spite of a high sugar content in blood, then it deteriorates to the degree of coma; (7) neurological symptoms are possible, especially focal convulsive attacks, phenomena of meningism. Unlike ketoacidosis, there is such an early differential diagnostic symptom as a decrease in concentration of free fatty acids due to a decrease in lipolytic

factors, especially in the activity of the suprarenal cortex and hypophysis.

Hypoglycaemic coma: adynamia, yawning, hypersomnia, tremor of the limbs, sensation of hot or cold, sensation of hunger (but not thirst), dizziness, headache, acute progress of coma, fixed gaze, quick reaction to intravenous injection of glucose, low body temperature, hyperaemia of the face; pale, damp and cold skin, sweating; pilomotor reaction, rapid arrhythmic pulse, arterial hypotension, fast breathing, diplopia, mydriasis, decreased tonus of the eyeballs, anxiety, motor and psychomotor excitement, delirium, hallucinations, tendon reflexes increased in the arms and decreased in the legs, Babinski's reflex, clonic convulsions, tonic spasms in the arm and leg muscles; leucopenia, lymphocytosis, hypoglycaemia.

When differentiating subarachnoid haemorrhage from *haemorrhagic meningoencephalitis*, one should take into account that the onset of a subarachnoid haemorrhage is often apoplectiform. Meningoencephalitis is characterized with chills, vomiting, psychomotor excitement. Subfebrile temperature in subarachnoid haemorrhage is not irregularly remittent. The eye fundus does not reveal congestion or neuritis like those in haemorrhagic meningoencephalitis; the symptoms are less labile; there are no remissions, no catarrhal phenomena or herpetic rash. In haemorrhagic meningoencephalitis, the cerebrospinal fluid pressure is usually raised, there is more protein, and pleocytosis is found there.

In some cases, haemorrhagic meningoencephalitis is differentiated from aneurysmal haemorrhage, in which temperature is elevated and the number of leucocytes in the blood is increased. An apoplectiform onset without the prodromal phenomena speaks against the diagnosis of haemorrhagic meningoencephalitis.

The epileptiform onset in subarachnoid haemorrhage gives grounds to differentiate it from *epileptic coma*. It is characteristic for subarachnoid haemorrhage that there is admixture of blood in the cerebrospinal fluid, changes in the eye fundus which are typical of hypertensive disease. Arterial pressure is often increased; typical are psychomotor excitation, meningeal phenomena, vomiting, elevated temperature, but there are no biting of the tongue, cyanosis, acute sweating, muscle hypotonia, and general areflexia characteristic of epileptic attacks.

Stroke should be differentiated from *traumatic coma*, which usually develops all of a sudden after an injury and is attended with bruises or haematomas. Often there is bleeding from the nose, ears, and mouth. The symptoms of traumatic coma are vomiting, bradycardia, slow respiration, pale face. Intracranial traumatic haematomas are characterized by a bright period followed by development of the secondary brain-stem syndrome with im-

paired consciousness and respiration, the alternating syndrome of cerebral peduncle lesion (mydriasis on the side of localization of the haematoma and signs of hemiparesis in the contralateral limbs). Craniogram reveals injury to the bones of the cranium. The cerebrospinal fluid is xanthochromic. Echoencephalography in intracranial haematoma shows a shift of the central cerebral structures to the side opposite to localization of the haematoma.

Clinical signs similar to stroke occur in patients with *haemorrhage into cerebral tumour*, into the perifocal area, and having general dyshaemic disorders with multiple haemorrhages into the hemispheres and the brain stem. It is important for diagnosis to establish the features of the course of the disease, peculiarities of focal symptoms, the degree of general cerebral symptoms prior to the stroke, and characteristic change in the eye fundus. The epileptic syndrome may occur both in stroke and in cerebral tumour.

In the differential diagnosis of a tumour from an aneurysm data from the case history are essential: recurrent haemorrhages, noise in the head synchronized with pulse, instability of motor and speech disorders are typical of a stroke due to an aneurysm in cerebral vessels.

Cerebral tumour is most likely to be differentiated from thrombosis of cerebral vessels, especially in older patients, when focal symptoms develop gradually, like in tumour, and general cerebral symptoms are mildly pronounced. Cerebral tumour is characterized by development of focal symptoms by the 'greasy stain' type: focal symptoms develop gradually, cardiovascular disorders are often absent, there is protein-cellular dissociation in the cerebrospinal fluid, the eye fundus not uncommonly shows congestion, echoencephalography reveals dislocation of the median structures.

4.12. Treatment of Cerebral Stroke

Treatment of patients with acute disturbances of cerebral circulation should be urgent and differentiated depending on the patient's status and the nature of the pathological process in the brain. A general diagram of recommended stages of treatment is shown in p. 157.

Early hospitalization is advisable in case of cerebral stroke in order to ensure active therapy, as well as surgical treatment. Urgent adequate medical aid should be rendered before transportation to hospital. Extra care should be exercised during transportation: the patient should be carried without jerks, maintaining the same position, the head higher than the trunk, when lifting him on the stretcher up or down the stairs.

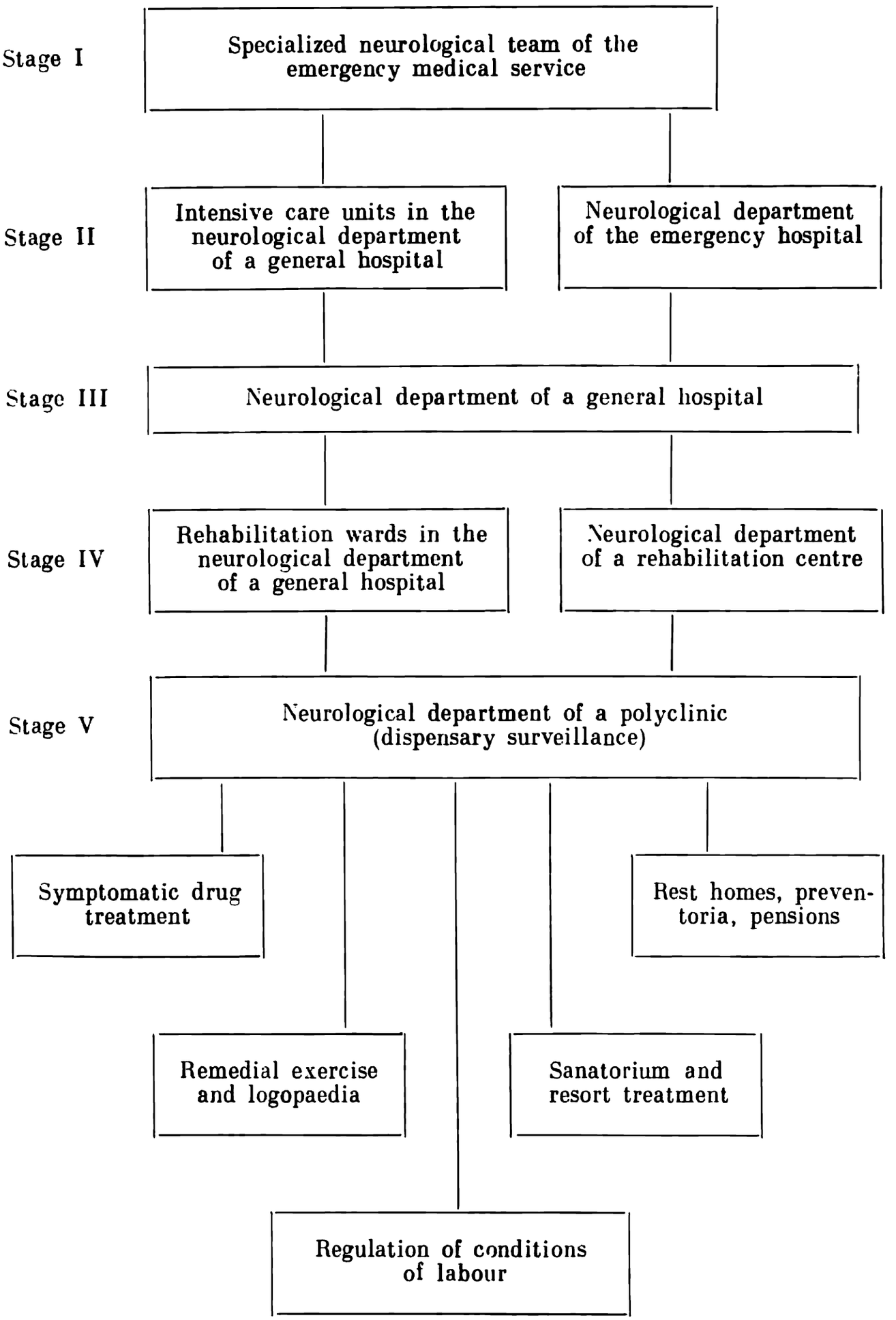


Diagram. The system of staged treatment of the patients with acute disturbances of cerebral circulation

Forms and methods of rendering special aid to stroke patients have been developed. In the larger cities there are special 'anti-stroke' teams including a neurologist, which are supplied with the necessary devices (ECG, echoencephalograph, etc.), and other means for rendering emergency therapy. The principal task of such a special team is to make an immediate diagnosis, to take appropriate measures to control the disease, to decide whether early hospitalization is necessary, and to carry the patient to a hospital.

Stroke patients should be put as early as possible into neurological hospitals or specialized neurological departments attached to hospitals, which provide combined treatment and have departments or wards for resuscitation and intensive care.

It is not advisable to put into hospital patients in the state of deep coma with gross impairment of the vital functions, acute disorder of cardiac activity, and decrease in vascular tonus; it is equally inexpedient to hospitalize patients with recurrent disturbance of cerebral circulation complicated by dementia and/or other psychic disorders, as well as those with an incurable somatic disease.

Emergency care. Emergency care measures regardless of the nature of the stroke (non-differentiated care) are aimed at relieving disorders occurring within the organism and include control of the factors predisposing to the spread and deterioration of the pathological process in the brain. All-important is to control disorder of the vital functions from the very outset.

1. *Treatment of acute cardiovascular disorders.* Insufficient cardiac function is treated with injection of 1 ml of 0.06 per cent convallaria (Corglycon) or 0.25-0.5 ml of an 0.05 per cent strophanthin solution with glucose (saline for diabetics) intravenously; nikethamide (Cordiamin), 2.0 ml; camphor oil, 2-3 ml of a 20 per cent solution.

Cardiac arrest requires immediate indirect massage of the heart with artificial respiration, and intracardiac injection of adrenaline or noradrenaline, as well as calcium chloride.

In development of collapse additional measures are applied both to improve cardiac function and regain normal tonus of the circulatory system. It is expedient to prescribe cardiac glycosides, pressor amines—a 1 per cent phenilephrine (Mezaton) solution, 1-2 ml subcutaneously, intramuscularly or intravenously; caffeine; ephedrine; noradrenaline; angiotensin (hypertensin); as well as corticosteroids, such as hydrocortisone, prednisolone, dexamethasone intravenously in a drip at the rate of 20-40 drops per minute in 250 ml of a 5 per cent glucose, Ringer or saline solution, or of a 4 per cent sodium bicarbonate solution.

With high arterial pressure, bendazol (Dibazole) is given, 6-12 ml of an 0.5 per cent solution or 2-5 ml of a 1 per cent solution; papaverine, 2-4 ml of a 2 per cent solution; Rausedil, 1 ml of an 0.1

per cent or an 0.25 per cent solution; clonidine (Haemiton), 1 ml of an 0.01 per cent solution; neuroleptics; diuretics like furosemide (Lasix), etacrynic acid (Uregit) intravenously or intramuscularly with due regard to arterial pressure prior to the stroke. Lytic cocktails including ganglioblockers such as azamethonium (Pentamine), trimetaphen camphor sulphonate (Arfonad), chlorpromazine (Aminazin) are given in haemorrhagic stroke.

2. *Treatment of respiratory disorders.* In stroke, respiration relief is a constituent of the whole system of treatment; its efficacy depends considerably on its application jointly with other therapeutic methods. The combination of medical measures consistently applied to ensure normalization of the respiratory function includes maintenance of patency of the respiratory tract. The following methods are used for that: (1) change of the lying patient's position; (2) cleaning the mouth; (3) fixation of the lower jaw; (4) use of oral or nasal air-feeders; (5) sucking off the secretion through a catheter with the aid of special suction devices; (6) intubation and tracheostomy (which are applied only when the measures preventing obstruction of the respiratory tracts fail).

Mucus is sucked off both immediately and later. Intubation and tracheostomy are resorted to in a sudden respiratory arrest, progressive respiratory disorders with appearance of abnormal breathing, bulbar or pseudobulbar symptoms entailing the risk of aspiration, growing congestive phenomena in the lungs with accumulation of the secretion in the respiratory tract. In case lung ventilation is inadequate even after the patency of the respiratory tracts has been restored, then either assisted respiration is set up (stimulation of the patient's insufficient breathing) or artificial respiration is established. A sudden respiratory arrest, when there are no respiratory and other devices, demands artificial mouth-to-mouth or mouth-to-nose respiration to be applied immediately. Artificial ventilation of the lungs is indicated for the patients with marked respiratory inadequacy or with no spontaneous respiration.

3. *Maintenance of homeostasis.* Unconscious patients are provided with compensation of the water-electrolyte balance and correction of the acid-base equilibrium. The volume of liquids to be introduced parenterally should be 2000-2500 ml daily in two or three stages. The liquids introduced are electrolyte-containing solutions (isotonic solution of sodium chloride, the Locke-Ringer solution), a 5 per cent glucose solution, dextran (Polyglucin, Rheopolyglucin).

Since disturbed acid-alkaline equilibrium is often associated with potassium deficit, potassium nitrate or potassium chloride is introduced up to 3-5 g daily. Maintenance of adequate ventilation of the lungs is necessary to correct the acid-base equilibrium. If independent respiration is insufficient, it is necessary to apply

an artificial respiration device of the type providing both active inhalation and active exhalation.

To eliminate acidosis, a 4-5 per cent sodium bicarbonate solution is introduced intravenously by the drip method, along with enhancement of lung ventilation, oxygen therapy, and measures to increase cardiac output. The simplest way to calculate the volume of a 5 per cent sodium hydrocarbonate solution to be injected is

$$X(\text{ml}) = 0.5 \times \text{BE (mole/l)} \times \text{body mass (kg)}.$$

where BE is the deficit of bases determined with the 'micro-Astrup' apparatus.

To eliminate metabolic acidosis, intravenous infusion of Trisamine is recommended (a 3.6 per cent solution in a dosage of 0.12-0.5 g per kg body weight at the rate of 1 ml/min). Trisamine infusion may be combined with sodium hydrocarbonate medication.

Metabolic alcalosis requires improvement of water balance, correction of hypokalaemia, hypochloraemia.

4. *Control of cerebral oedema.* It is recommended to give aminophylline (Euphylline), 10 ml of a 2.4 per cent solution intravenously or 1 ml of a 24 per cent solution intramuscularly; saluretics: furosemide (Lasix), etacrynic acid (Uregit) intramuscularly or intravenously. 'Lytic' mixtures are also used, containing neuroplegics—chlorpromazine (Aminazin), antihistaminic preparations—diphenhydramine (Dimedrol), promethazine (Pipolphen), procaine (Novocaine). In order to lower permeability of the vessel wall, the mixture is added with ascorbic acid. An exemplary prescription of a lytic mixture: 400-500 ml sodium chloride isotonic solution, 50-60 ml 0.5 per cent procaine (Novocaine), 2 ml 1 per cent diphenhydramine (Dimedrol), 5-10 ml 5 per cent ascorbic acid. The mixture is to be given in a drip at a rate not exceeding 50 drops per minute.

Hydrocortisone, prednisolone may be used as well, but not in hypertension; their use demands increase in potassium salts.

Glycerine is prescribed (at a dosage of 1 g/kg) mixed with water or some fruit juice 1 : 2 or 1 : 3; in case of dysphagia the mixture is introduced through a nutrition probe. It may be advisable to prescribe rectal instillation of 20 per cent glycerine dissolved in isotonic solution of sodium chloride at 38°C (in a dosage of 0.5 g/kg). The first 50 ml are to be introduced into the ampulla of the rectum with the aid of a special dropper at the rate of 120-130 drops per minute, and the rest at the rate of 30-40 drops.

Mannitol (Osmitrol) may be used for dehydrating in proportion of 0.5-1.5 g of dry substance per kg body weight. The dosage is dissolved in 200 ml saline or 5 per cent glucose and then introduced intravenously in a drip. In rectal instillation, 30 per cent mannitol is given in isotonic sodium chloride solution, warmed up to

38°C. in a dosage of 0.5 g/kg. The first 80 ml are instilled into the ampulla at the rate of 120-150 drops per minute, and the rest at the rate of 30-40 drops per minute.

5. *Treatment of hyperthermia and other vegetative disorders.* When the body temperature is about 40°C or more, 10 ml of aminophenazone (amidopyrine) in a 4 per cent solution or 2-3 ml of Analgin in 50 per cent solution is given intramuscularly. The temperature may be lowered also by the 'lytic' combinations including diphenhydramine (Dimedrol), procaine (Novocaine), aminophenazone (amidopyrin). Rubbing the body with alcohol solution 'until red' is indicated, since it increases emission of heat. Regional hypothermia of larger vessels is recommended as well (ice-bags to the area of the carotids, axillary and groin regions; wrapping into damp sheets). The air in the room should be cool, a fan to be put to the head of the bed, a sheet to be used instead of a blanket.

Differential treatment of cerebral strokes. Treatment of *haemorrhagic stroke* aims at (1) elimination of cerebral oedema and lowering intracranial pressure; (2) lowering arterial pressure in case it is considerably high; (3) raising coagulability of the blood and lowering the permeability of the vessel walls; (4) re-establishment of vital and vegetative (autonomic) functions. The patient should be put to bed cautiously, the head higher than the feet (the head of the bed may be slightly tilted), and local hypothermia is advisable, i.e. ice-bags around the head or a special device for regional hypothermia.

To put arterial pressure down, Rausedil, chonidine (Haemiton), bendazol (Dibazole), aminophylline (Euphylline) are given. In case there is no effect and arterial pressure is acutely high, chlorpromazine (Aminazin) is given, 2 ml of a 2.5 per cent solution in 5 ml of 0.5 per cent procaine (Novocaine) intramuscularly. It may also be given in a 'lytic' mixture: 2.5 per cent Aminazin—2 ml, 1 per cent Dimedrol—2 ml, 2 per cent trimeperidine (Promedol)—2 ml intramuscularly. Ganglioblockers are recommended: azamethonium (Pentamine), 1 ml of a 5 per cent solution intramuscularly or 0.5-1.0 ml of the same in 20 ml of 40 per cent glucose intravenously slowly under continuous control of arterial pressure; Benzohexonium, 1 ml of a 2 per cent solution intramuscularly; hexamethonium (Hexameton), 1 ml of a 2 per cent solution intramuscularly; trimetaphen camphor sulphonate (Arfonad), 5 ml of a 5 per cent solution in 150 ml of 5 per cent glucose or isotonic sodium chloride in a drip, beginning with 30-50 drops per minute and increasing the rate to 120 drops. Aminazin and ganglioblockers may be introduced as well intravenously in a drip, dissolved in saline, Ringer or 5 per cent glucose solution. An exemplary prescription of the medication: isotonic sodium chloride—250 ml, 5 per cent glucose—250 ml, 5 per cent azamethonium (Pentamine)—1-2 ml or 2 per cent ben-

zohexonium 1-2 ml, 2.5 per cent Aminazin—1-2 ml, 1 per cent Dimedrol—1-2 ml.

Active hypotensive preparations should be applied cautiously in haemorrhagic stroke associated with acute intracranial hypertension. When arterial pressure is low enough to be optimal for the patient (individually), hypotensive medication should be withdrawn. When there is vasoplegia, lowering arterial pressure with drugs in case of acute intracranial hypertension may result in complete circulatory arrest and affect the brain irreversibly. Since acute intracranial hypertension is present in parenchymatous and subarachnoid haemorrhages in almost a hundred per cent of the cases, active hypotensive therapy in haemorrhagic stroke should be combined with dehydration measures.

Preparations enhancing blood coagulability and decreasing vascular permeability are indicated: calcium preparations (10 ml of a 10 per cent calcium chloride solution intravenously or the same of calcium gluconate intramuscularly), 2 ml of a 1 per cent menadione sodium bisulphite solution (Vikasol) and 5-10 ml of 5 per cent ascorbic acid intramuscularly; Rutoside (Rutin, vitamin P), Rutamin—1 ml once or twice daily subcutaneously or intramuscularly; gelatin—20-50 ml of a 10 per cent solution intramuscularly or intravenously.

In order to produce an effect on fibrinolysis and to decrease blood fibrinolytic activity and permeability of the vessel walls, and to inhibit kininogenic enzymes aprotinin (Trasylol), Contrical, or epsilon-aminocaproic acid may be used under control of both fibrinolytic activity and fibrinogen content. Contrical or aprotinin (Trasylol) is introduced in a dosage of 20 000-30 000 units intravenously in a drip. Epsilon-aminocaproic acid is also administered intravenously in a drip, as a 5 per cent solution in isotonic sodium chloride (up to 100 ml). Elevated vessel-wall permeability and an erythrodiapedetic haemorrhage indicate the use of Dicinon in a dosage of 2 ml (250 mg) intravenously or intramuscularly. It is advisable not to give antifibrinolytics in pronounced atherosclerosis to avoid thrombotic complications.

To reduce intracranial pressure and eliminate cerebral oedema, it is recommended to apply furosemide (Lasix), 20-40 mg intravenously or intramuscularly; etacrynic acid (Uregit), 50 mg dissolved in 20 ml of 40 per cent glucose, intravenously; glycerine; mannitol (Osmitrol). It is expedient to combine the use of different dehydrative medications. The highest capability to potentiate mannitol have Uregit, Lasix, and Euphylline. Hormonal preparations are used to control oedema: hydrocortisone (ampules containing 0.025 or 0.05 g of the preparation with dissolvent attached), prednisolone (1 ml ampules containing 30 mg of the preparation), and dexamethasone (1 ml ampules containing 0.004 g each); the drugs

have anti-inflammatory and desensitizing effect and lessen vascular permeability. It is however undesirable to give these preparations in hyperglycaemia and considerable arterial hypertension.

Surgical treatment (see 'Surgical Treatment of Stroke') is indicated in extensive neurological symptomatology, deterioration in the patient's condition with haemorrhage into the brain and especially when there is immediate danger to his life.

The **treatment of ischaemic stroke** is directed at improvement of brain blood supply. To this end it is necessary to regain normal cardiac function and arterial pressure, to build up the inflow of blood into the brain by means of dilatation of regional cerebral vessels, reduction of vascular spasm, improvement of collateral circulation, normalization of coagulability and rheological properties of blood, enhancement of the resistance of cerebral tissue to hypoxia, and improvement of cerebral metabolism.

With cerebrovascular insufficiency developing while arterial pressure is reduced and cardiac function weakened, cardiac glycosides are indicated: strophanthin, convallaria (Corglycon), and pressor amines: phenylephrine (Mezaton), ephedrine, noradrenaline, as well as corticosteroids: hydrocortisone, prednisolone, dexamethasone in 250-500 ml of 5 per cent glucose or Ringer solution, given in a drip at the rate of 20-40 drops per minute.

To improve cerebral blood supply and collateral circulation, vasodilatators are applied: Euphylline, 10 ml of a 2.4 per cent solution intravenously; 2 per cent No-spa, 2-4 ml intramuscularly.

More active vasodilatators are indicated in raised arterial pressure: papaverine, bencyclane furoate (Halidor). It is recommended to apply active vasodilatators in the first hours of cerebrovascular embolism, when reflex vascular spasm contributes to ischaemization of cerebral tissue. These are the cases in which Halidor, papaverine, No-spa, Euphylline are indicated. The patients are usually treated with the vasodilatators (Euphylline, No-spa) for 7-10 days. The following preparations are also given: nicotinic acid (Niacin), 1 ml of a 1 per cent solution with glucose intravenously; Instenon, 1-2 ml intramuscularly or 1-2 dragées 3 times daily during or after meals; cinnarizin (Stugeron), 0.025 g 3 times daily; xantinol nicotinate (Complamin) 2 ml 1-2 times daily intramuscularly or intravenously. Also applied are the following vasoactive preparations: Eutergin, hexobendine, cyclandelate, clofibrate betahistamine (8 mg per os 4 times daily); isoxsuprine, 100 mg in 500 ml of 5 per cent fructose (laevulose); phenoxybenzamine, Conamicin, pyritoxine, ethylendiamintetracyclic acid, Trental (5 ml ampules containing 100 mg of the preparation).

Venous outflow may be improved by introduction of thiamine pyrophosphate (cocarboxylase), 50 mg, and dietifen, 10 mg. Vasodilatative effect may be reached by means of inhalation of hypercapnic

mixtures: 7 per cent CO_2, 43 per cent O_2 and 50 per cent atmospheric air; 3-6 sessions a day for 5-10 minutes each. To improve microcirculation and collateral circulation in the area of cerebral infarction, and to reduce the activity of the coagulation blood system, the haemodilution method is applied. Haemodilution is accomplished by intravenous instillation of dextran (polyglycin or rheopolyglycin) in a dosage of 800-1200 ml daily. Each dose of polyglycin or rheopolyglycin, 400 ml, is given intravenously in a drip at the rate not exceeding 20 drops per minute. The patients are treated with haemodilution for the first 5-7 days from the onset of the stroke, provided thrombolytic therapy has not been given simultaneously. The method should not be used with intracerebral and/or arterial hypertension.

Anticoagulants may be given if there is no doubt in the ischaemic nature of the stroke, no general contraindications, and if arterial pressure is no more than 200/110 mm Hg. Heparin is administered in the acute period of ischaemic stroke, 5000-10 000 units intravenously in 10 ml of isotonic solution or intramuscularly under control of blood coagulability 4 times every 24 hours. Heparin treatment is continued for 3 days; 24 hours before heparin is discontinued, anticoagulants of indirect action are given: phenindione (Phenyllin), 0.03 g 2 times a day; Sincumar, 0.004 g 1-2 times a day, or hydroxymethylphenindione (Omephin), 0.05 g 1-2 times a day. Treatment with the indirect-action anticoagulants is carried out under control of the prothrombin index which is determined at least once every 2-3 days (it may be decreased to 40-50 per cent), and repeated urine tests. The influence of indirect-action anticoagulants reaches its maximum in 24-72 hours. The optimal reduction of coagulation indices in the process of anticoagulant therapy is characterized by lengthening of the relevant values of coagulogram by 1.5-2 times, and those of thromboelastogram by 2.5-3 times. Further on maintenance doses are to be administered which are strictly individual. Treatment with indirect-action anticoagulants lasts for 2-3 months.

Thrombolytic therapy is indicated in thrombosis and embolism. It is recommended to give either fibrinolysin or preparations activating the fibrinolytic system of the organism (streptokinase, urokinase). Urokinase compared to streptokinase has a number of points to its advantage: it has no antigenic properties, and it causes considerably less pronounced changes in the coagulation blood system. While taking a decision on treating with streptokinase or urokinase, it is important to bear in mind that first, it is difficult to overrule a possibility of microfocal intracerebral haemorrhage in ischaemic stroke, and second, it is necessary to evaluate the condition of ischaemized tissues, insofar as irreversible transformation in them is concomitant with necrotic damage.

Fibrinolysin is given together with heparin. Fibrinolysin treatment is prescribed in the first hours, the first 24 hours from the onset of the stroke. It is carried out under control of the coagulation time, coagulograms and thromboelastograms. The initial dose of fibrinolysin is 20 000-30 000 units, which is dissolved in 300-350 ml of saline. The ampule is added with 10 000-15 000 units of heparin, and the mixture is given intravenously in a drip at the rate of 16-20 drops per minute for 4-5 hours. Intramuscular heparin injections (5000-10 000 units) are given 4 times daily. Fibrinolysin is introduced once or twice, occasionally 3 times, depending on thromboelastogram and the time of blood clotting. Heparin is injected in the meantime between instillations of fibrinolysin with heparin, and also for 2-3 days more after termination of the fibrinolysin-heparin therapy.

To reduce aggregation of thrombocytes, the following preparations may be given: acetylsalicylic acid (Aspirin), xantinol nicotinate (Complamin), pyridinol carbamate (Anginin), 1-2 tablets 3 times daily; Trental, 100 mg 1-2 times daily per os or intravenously; Dipyridamol, 0.025 or 0.075 g tablets or dragées, an 0.5 per cent solution in 2 ml ampules; calcium dobesilate (Doxium), 250 mg 2-3 times daily or 2-4 ml intravenously or intramuscularly.

Means and preparations contributing to the resistance of the brain to hypoxia are applied. These are regional hypothermy and the inhibitors of tissue metabolism (various neuroleptics, barbiturates and preparations with narcotic action). Craniocerebral hypothermy may be applied as well: an ice-cap, a fan at the head of the bed, a special helmet for controlled hypothermy within the 32-34°C range. Patients in sopor or coma with an acute rise in temperature are given antipyretic preparations: Rheopyrine, 5 ml; 4 per cent aminophenazone (amidopyrine), 10 ml; and 50 per cent noramidopyrine methanesulphonate (Analgin), 1-2 ml, intramuscularly. To reduce the damage to the brain structures done by hypoxia, it is advisable to give diazepam (Seduxen), 2 ml of an 0.5 per cent solution intravenously 2-3 times daily, alpha-tocopherol acetate (Vitamin E), 1 ml of a 5-10 per cent solution intramuscularly.

It is expedient also to apply sodium oxybutyrate helping to raise the resistance of brain tissue to hypoxia. It is to be given in a dosage of 50-100 mg/kg or 10 ml of a 20 per cent solution intravenously slowly. Also indicated are preparations influencing nervous tissue metabolism and improving oxygen consumption: adenosine triphosphate (ATP), thiamine pyrophosphate (cocarboxylase), pyridoxine (vitamin B_6), pangamic acid sodium salt (vitamin B_{15}), alpha-aminoglutaric (glutamic) acid; Aminalon, Gammalon introduced intravenously in a drip at the rate of 40 drops per minute—20 ml of a 5 per cent solution in 300-500 ml of isotonic sodium chloride or 5 per cent glucose, every day for 3-5 days; cerebrolysin, 1-2 ml 2-3

times a week intramuscularly or intravenously in a drip, 10 ml in 200 ml of isotonic sodium chloride for 1-2 hours every day, up to 8-10 instillations; Glyo-6, 6 capsules or 400 mg a day intramuscularly; Vincamin in a single dose of 80-90 mg in saline intravenously in a drip, then intramuscularly 40-60 mg a day; Desclidium (vicvisine chloralhydrate), 0.1 g 3 times daily, pyracetam (Nootropyl), 5 ml (1 g) intravenously or intramuscularly up to 3 times a day, or 2 capsules, 400 mg each, 3 times daily per os.

The means of antihypoxia therapy are advisable to be combined with preparations to compensate or correct the action of other pathogenic factors of cerebral infarction: vasoactive means, antioedemic therapy, drugs to normalize microcirculation. Derangement of consciousness, bradycardia and vomiting, growing of the brain-stem symptoms indicate necessity to introduce mannitol (Osmitrol) or glycerin (glycerol). Corticosteroids may contribute to the action of hypertensive solutions and diuretics; they are recommended as maintenance dehydration therapy immediately following the use of active antioedemic means.

One of the methods of treatment of ischaemic stroke is *hyperbaric oxygenation* which may be applied in an integrated therapy, especially in the acutest and acute periods of stroke. The sessions are repeated depending on the patient's condition, indices of the blood gas content and acid-base equilibrium, as well as changes in the cardiovascular system.

Prophylaxis of complications. To prevent *pneumonia*, it is recommended to tilt a little the head of the bed, to turn the patient regularly, clean the cavities of the mouth and nose, and suck off the secretion of the respiratory tract. Antibiotics and sulphanilamide preparations are to be given at the first signs of pneumonia.

Treatment of *pulmonary oedema* should be multiple in its approach and differentiated. With pulmonary oedema of neurogenous origin developing while the condition of the cardiovascular system is satisfactory, it is recommended to apply gangliоblockers—benzohexonium, azamethonium (Pentamine), tetryllammonium (Tetamon), neuroplegics—chlorpromazine (Aminazin), dehydrobenzperidol (Droperidol), and preparations with pronounced antihistaminic effect—diphenhydramine (Dimedrol), promethazine (Pipolphen), Suprastin. In case pulmonary oedema is caused by acute heart failure (of the left ventricle), the complex of measures should be aimed at relieving the lesser circulation by means of introduction of cardiac glycosides—strophanthin, convallaria (Corglycon); if there is a drop in arterial pressure, phenylephrine (Mezaton) is recommended. Special suction devices should maintain patency of the respiratory tract, and antifoam means are applied—inhalation of 96° ethanol or a 10 per cent antifoamsylan alcohol solution through an oxygen inhalator. Severe cases of pulmonary oedema require tracheostomy.

Furosemide (Lasix), concentrated plasma solutions intravenously are applied for dehydration. In order to reduce venous inflow to the heart, the patient is put into an elevated position, tourniquets are put to the limbs; bloodletting is recommended when there are high arterial pressure and stenosis of the mitral valve.

Thromboembolism of the pulmonary artery in stroke may cause a fatal outcome. Proper treatment should be started immediately. Analgesics are employed (if there is a pain syndrome), cardiovascular preparations—strophanthin, Corglycon, pressor amines, fibrinolytic agents and direct-action anticoagulants.

Retention of urine may be relieved by a hot water bag put to the area of the urinary bladder. If that is not effective, it is necessary to catheterize the bladder twice a day.

Constipation should be relieved by enema, which is better to be a hypertensive one: 200 ml of a 20 per cent magnesium sulphate solution plus 200 ml of water. If necessary, the enema is put every 2-3 days.

To avoid bedsores, it is important to regularly smooth out creases of the sheets and uneven spots of the mattress, to rub the body clean with camphor alcohol and powder the skin folds with talc; it is better to put an inflatable ring under the patient and apply cotton bandages to the heels and sacrum.

Treatment of certain signs of cerebral stroke. Dyscirculatory phenomena in the vertebrobasilar system, as well as an acute rise in intracranial pressure are accompanied with repeated attacks of *vomiting*. The best antiemetic is dehydrobenzperidol (Droperidol). At the same time Droperidol allows psychomotor excitement and uncontrollable hiccup to be arrested. Antihistaminic preparations are also effective antiemetics. *Hiccup*, which is not dangerous but still causing disorder of the respiratory cycle, is treated, save from Droperidol, with atropine, Aminazin. It is recommended also to give 0.25 per cent procaine (Novocaine) per os. Procaine blockade of the phrenic nerve may be applied as well.

Psychomotor excitement is a common complication of stroke with localization in the right hemisphere, subarachnoid haemorrhage or repeated epileptic attacks. The patient is given then Droperidol or Haloperidol intramuscularly, sodium oxibutyrate intravenously, diazepam (Seduxen) intravenously or intramuscularly. If that is not effective, barbital anaesthesia is applied.

Epileptic status calls either for giving diazepam in a dosage of 2 ml intravenously or for barbital anaesthesia—70-80 ml of a 1 per cent or 20-30 ml of a 2.5 per cent hexobarbital (Hexenal) solution intravenously slowly. If there is no effect and the attacks repeat, artificial lung ventilation is carried out together with introduction of muscular relaxants, inhalation anaesthesia with nitrous oxide and oxygen mixture, and prolonged instillation of anticonvulsive

drugs: 50-70 ml of diazepam or 0.5 per cent hexobarbital solution intravenously in a drip. It is necessary also to introduce an anticonvulsive mixture including 0.3 g phenobarbital (Luminal), 0.1 g phenytoin (Diphenin), 0.1 g sodium amobarbital (sodium Amytal) through a gastric tube.

Prevention of muscular contractures. In order to prevent muscular contracture, the paralysed arm should be laid aside extended and supinated with the fingers extended and spread wide; they may be thus fixed by means of small sand-bags, longettes or a special device for the prophylaxis of contractures in the paralysed arm; this makes it possible to fix the hand extended and preventing flexo-pronated position in the ulnar and brachial joints. The procedure is to be repeated several times a day for 15-20 minutes. A cotton roll should be put under the knee joint of the paralysed leg, and the foot is fixed in dorsal flexion either with the aid of a rubber tie or putting a wooden box against it. It is advisable to apply a special device for the prophylaxis of contractures of the paralysed leg which is to be fixed with the patient either in a lying or sitting position and thus preventing contracture of the extensors of the foot, and rotated or extended position in the knee joint.

Nutrition. In case the condition of the patient is not severe and there is no dysphagia, the diet for the first day should consist of some fruit and berry juices and sweet tea; from the second day the diet is to be extended; in the main, it includes some easily digested foods. In dysphagia, the patient is fed through a nasogastric tube. An unconscious patient is to be fed for the first two days parenterally with liquids containing electrolytes, a 5 per cent glucose solution and plasma-substituting solutions; later he is fed with nutritive mixtures through a nasogastric tube. Before infusing the nutritive mixture one should ascertain that the other end of the tube is in the stomach. This is indicated by the absence of cyanosis, and auscultation of the specific noise over the epigastric area when 20 c.c. of air is introduced through the tube by means of a syringe.

Exemplary contents of the nutritive mixture to be fed through the nutritive tube are: 1 l vegetable or groats decoction, 500 ml milk, 100 g granulated sugar, 50 g butter, 40 g oatmeal, 60 g egg powder. The daily volume of the mixture is divided into 5 portions, which are introduced over equal intervals. Every portion is added with polyvitamin powder during feeding time. For diabetics, the contents of the mixture should be changed accordingly.

To be certain that the stomach is emptied at a sufficient rate, one should check it sucking out its contents with the Janet syringe and measuring the volume.

4.13. Surgical Treatment of Stroke

The kind of surgical treatment, as well as concomitant drug treatment, are determined above all by the nature of the specific case of stroke.

In *haemorrhagic stroke*, surgical treatment is aimed at elimination or prevention of the progressing of the principal disease factors which might lead to a fatal outcome though haemorrhage itself does not cause vital damage to the brain. Those factors are fast growth of intracranial pressure and toxic effect of the products of degeneration of the extravasated blood causing oedema of the brain, its displacement, intrusion into it, and multiple secondary haemorrhages into the brain stem.

Intracranial bleeding due to a rupture of an arterial or arteriovenous aneurysm is often subarachnoid, therefore surgical intervention prevents another haemorrhage. With intracerebral haematoma, intervention is reduced to evacuation of the extravasated blood and making up certain decompression.

Most writers consider the following as contraindications to surgical intervention: multiple primary focal vascular lesions, combination of the principal disease with a gross lesion in the heart or kidneys, phenomena of azotaemia, and decompensated diabetes. Some of the writers assume as contraindications also severe condition of the patient after stroke, arterial hypertension, age over the middle, deep localization of the haemorrhage, flow of the blood into ventricular system.

Analysis of the outcomes of surgical treatment provides grounds to consider the preferable time for intervention in the end of the first week or the second or third week after the stroke, though other writers recommend to perform an operation as soon as possible when early removal of the extravasated blood may actually prevent the sequelae of the haemorrhage.

Preparation of the patients to operation includes a number of conservative methods of treating haemorrhagic stroke.

The surgery is done with both local anaesthesia and general (intravenous or more often endotracheal). The patients are laid on the operation table most often laterally on the side opposite to the focus of haemorrhage into the cerebrum and on the same side if the haemorrhage is into the cerebellum. Operation is performed only on the focus.

Ligation of the major arteries in haemorrhagic stroke is a matter of history only, since it has not proved to be useful. Intracerebral haematoma may be evacuated by means of either paracentesis with subsequent aspiration of the liquid contents, or dissection of the

brain to open the cavity of the haematoma and remove the liquid and clots of blood. Paracentesis as an independent therapeutic measure is applied relatively seldom, since it either brings about only temporary relief or there is no improvement at all; however, paracentesis of the brain is used widely for diagnosis. Most surgeons perform radical removal of intracerebral haemorrhage by means of opening the cavity of the haematoma, evacuation, and often subsequent drainage for 24-48 hours. When blood has breached into the cerebral ventricles, it is washed out either through the cavity of the haematoma and the defect in the wall of the ventricle, or by means of infusion of sodium chloride isotonic solution into the lumbar sac and removal with the reverse flow through the defect in the wall of the ventricle or through a drainage cannula introduced into the lateral ventricle.

The postoperative treatment includes a number of measures aiming at prevention of recurrent haemorrhages and cerebral oedema, at normalization of the vital functions, and prevention of disorders of water and salt balance.

The outcomes of the surgical treatment of haemorrhagic stroke are better in younger patients operated on for an aneurysm rupture. The least favourable outcomes are in the patients operated on in coma, with medial haemorrhages and extravasation of blood into the lateral ventricle, especially into the third one.

In *ischaemic stroke*, there are two kinds of surgical treatment possible: intervention into the brain in the area of the focus of softening and operation on the major vessels responsible for development of the ischaemic focus in the brain. The science of physiology has not yet established any substantiated clinical indications for surgical intervention into cerebral softenings, and that is why this kind of operation is performed rarely. During the past two decades operations on the major vessels of the head have been becoming more and more common, though they are mainly performed for treating transient disorders of cerebral circulation, but not for ischaemic stroke (cerebral infarction) characterized by stable loss of some brain functions.

Surgical intervention may only be undertaken for those kinds of ischaemic cerebral lesion when impairment of the blood flow occurs in the major vessels. Most operations are performed on the carotid arteries, then on the vertebral, innominate, subclavian, and middle cerebral arteries. In every such case, surgical intervention is due to an occlusion or stenosis of these arteries (most often of the atherosclerotic origin); another reason for operating on the intracranial part of the internal carotid and middle cerebral arteries may be embolism.

The basic method of determining the point of occlusion or stenosis in a vessel is angiographic study, which is desirable to be con-

ducted for all the four brain supplying arteries, since indications for surgical treatment depend on the state of collateral circulation and multiple lesions are often revealed.

When a stroke is due to an acute thrombosis, restoration of blood flow in the vessel and regression of neurological symptomatology can be only due to thrombectomy or thrombintimectomy performed within the first 48 hours after the onset of thrombosis. That leads however to a high risk of blood extravasation into the softened area. Besides, the period of acute development of the clinical phenomena does not necessarily coincide with the period of thrombus formation. Not uncommonly even complete occlusion in a vessel may be clinically asymptomatic for a long time, and acute development of cerebral infarction occurs only when collateral circulation is disturbed due to acute cardiac weakness or propagation of thrombosis over the vessels of the circle of Willis. These are cases when restoration of normal blood flow is not possible. Attempts to restore the blood flow by means of washing the vessel with fibrinolysin-heparin mixture are undertaken in operations on the major arteries during the first 24 hours, and by the data presented by some writers even within a week or two after the onset of thrombosis. During the later period resection of the initial part of the internal carotid may be attempted in order to prevent proximal spread of the thrombus, and some surgeons clip the supraclinoid part of that artery to arrest the spread of the thrombus into the intracranial cerebral vessels. Desympathization of the carotid sinus or removal of the superior servical sympathetic ganglion is performed, which causes dilatation of cerebral vessels and may improve collateral circulation. Embolism of the area of bifurcation of the internal carotid or the initial parts of the middle cerebral artery calls for embolectomy, i.e. removal of the embolus through a dissection in the vessel which ensures its patency. A method has also been elaborated to provide sufficient circulation in the ischaemized area of the brain by establishing an anastomosis between the branch of the middle cerebral artery distal to the place of the occlusion and the superficial temporal artery.

In case angiography shows stenosis of extracranial cerebral vessels, the indications for an operation are transient symptoms of lesion in the brain structures or persistent though not yet gross neurological symptoms; an intervention is urgent in case of the 'stroke-in-evolution'. Some writers consider that surgical treatment is indicated only when the lumen of the major artery is more than 50 per cent stenosed, even at the asymptomatic stage. Apart from the common ones, contraindications are considered to be pronounced general atherosclerosis, postinfarction condition, frequent attacks of angina pectoris. When occlusion of a vessel is combined with stenosis of another, surgical intervention is usually performed on

the stenosed vessel even in the case neurological symptoms provide the evidence on a cerebral lesion in the territory of the occluded vessel. This ensures better collateral circulation. The essence of the operation for stenosis is elimination of the obstruction to the adequate blood flow in the vessel. That is achieved by removal of the atheromatous plaque (atheroendarterectomy) and widening of the vascular lumen by means of putting a patch on the laterally dissected wall of the vessel, separation of the vessel from perivascular cicatrized adhesions, that compress it, strengthening of a loop or dissection of a kinked and stenosed part of the vessel with its subsequent suturing 'end to end', putting a prosthesis on the resected part of the affected vessel or providing a by-pass for it. In case the vertebral artery is compressed in the bone canal by an osteophyte, the latter is removed. Restorative operations on the vessels call for complete though temporary arrest of the blood flow along the vessel which may become a cause of severe cerebral ischaemia itself. To avoid that temporary internal or external shunting and hypothermia are applied; the operation is performed at high level of arterial pressure. During the intervention, the vessel is washed with anticoagulants, sometimes recurrently.

In the main, operations are performed with endotracheal anaesthesia, though some surgeons prefer to operate the carotids with local anaesthesia.

After the operation most of the surgeons check the condition of the restored artery with additional angiography. In the postoperative period, anticoagulants are applied for 5-6 days, apart from drugs correcting cardiovascular activity.

The outcomes of operations on the major cerebral vessels are far better in stenosis than in complete occlusion; postoperative morbidity rate in some clinics is as low as 1.5-1.0 per cent; the absence of neurological symptoms in prophylactic interventions reaches as much as 90 per cent and more.

The most common complications after operations on the major cerebral vessels are haemorrhage into the softened area of the brain and rethrombosis.

4.14. Rehabilitation

Rehabilitation after stroke is different depending on the period: (1) immediately after the stroke it is recommended to apply respiratory and general strengthening exercises, position therapy, methods of disinhibitive therapy—i.e. passive, reflex and active movements, logopaedic exercises for treating speech disorders; drug therapy—Aminalon, Turigeran, Cerimon, glutaminic acid, Encephabol, cerebrolysin, Inosie 'F', pyracetam (Nootropil), metandie-

none (Nerobol) and other preparations enhancing metabolic processes in the brain tissues; anticholinesterase agents—neostigmine (Proserine), galantamine; with raised tonus of the skeletal muscles —methyl-p-tolylpiperidinepropanone (Midocalm, Mydeton), Scutamyl 'C', tropine diphenylacetate (Tropacin, Tropazine), methylisaconitine (Mellictine), Condelphyn, Elatyn, Lyoresal, etc.;

(2) during the period of restoration of disturbed functions it is recommended to go on with respiratory and general strengthening exercises, position therapy, methods of disinhibitory therapy used more widely—drugs, passive and active movements, various kinds of massage, electrostimulation, logopaedic exercises;

(3) during the recovery period, active movements, remedial exercise, physiotherapy are indicated;

(4) during the completing phase of treatment, rehabilitation is provided for in medical institutions of the sanatorium type in the country, in rehabilitation departments of hospitals or sanatoria for cardiovascular patients;

(5) during the period when the sequelae of the disturbances of cerebral circulation may show, rational day-time schedule is recommended, including occupational therapy, correct nutrition; in case the capacity for work has been restored, rational job placement is recommended with due regard to the working experience and inner compensatory ability of the patient; it is necessary to maintain steady out-patient follow-up by a neurologist and a therapeutist, to conduct general hygienic, therapeutic, and prophylactic measures.

4.15. Clinical Course

In the main, stroke has three variants with regard to its course: (1) favourably regressive course, when the disturbed functions gradually restore in full; (2) alternating, remittent course, when the condition of the patient deteriorates periodically due to concomitant pneumonia, recurrent strokes and other complications; the outcome is favourable; (3) progressive course with gradual growth of symptoms and the fatal outcome. The course of stroke depends on the nature of the vascular process, its localization, size, the rate of development, and complications. Recurrent disturbances of cerebral circulation are possible.

The most severe complications of *haemorrhagic stroke* are cerebral oedema, breach of the blood into the ventricles of brain, the compression and dislocation of the brain stem.

In extensive hemispherical haemorrhages, complicated by early extravasation of blood into the ventricles, coma develops at once, overshadowing focal symptoms, and the fatal outcome rapidly en-

sues, in a matter of several hours, sometimes immediately after the stroke. Equally soon comes death in haemorrhage into the cerebellum or the brain stem complicated with extravasation of the blood into the fourth ventricle. The mortality rate for cerebral haemorrhages is high, and according to various statistics it is in the range of 60 to 90 per cent. Most of the patients die within the first 48 hours, most of them within 24 hours. The morbidity rate is especially high in haemorrhages into the brain stem and the cerebellum.

With limited lateral hemispherical haematomas consciousness usually is not much impaired. However, with the growth of the haematoma in size and its extravasation into the cerebral ventricles the fatal outcome is seen within 24-48 hours after stroke. With limited bleedings into the hemispheres of the brain without considerable cerebral oedema and extravasation of blood into the ventricles, the patients' condition first stabilizes, then becomes better: consciousness is clear, vegetative disorders lessen, signs of secondary brain-stem syndrome disappear, focal symptoms gradually decrease. The period of early muscular hypertonia and diaschistic hypotonia is followed (more common from the third week of disease) with late hemiplegic hypertonia of the spastic type with characteristic Wernicke-Mann posture (flexion of the forearm, pronation and flexion of the hand, flexion of the fingers, extension of the femur and the crus). The residual phenomena are usually present, though sometimes they are not pronounced. Favourable course is possible with limited bleeding into the cerebellum and the brain stem.

In most patients with *ischaemic stroke*, condition is most severe for the first 2-3 days. Then there is a period of improvement which is seen as some stabilization of symptoms in some patients and their decrease in others; the rate of restoration of the impaired functions varies, it may be rapid or torpid. Restoration of functions begins on the first day of the stroke or several days after, in some patients only in several weeks. Occasionally ischaemic stroke may take a severe course. The morbidity is observed in about 20 per cent of cases. Recurrent ischaemic strokes lead to the pseudobulbar syndrome, progressive psychic disorders.

4.16. Prognosis

Prognosis in stroke depends on the aetiology and clinical course of the vascular disease, development of collateral circulation, localization, size, the rate of growth, nature of the pathological process in the brain, and complications. Unfavourable prognostic signs in haemorrhagic stroke are gross impairment of consciousness (especially early development of coma), appearance of oculomotor

disorders, hormetony, decerebrate rigidity or diffuse muscular hypotonia, disorders of vital functions, pharyngeal paralysis, hiccup. Prognosis is better in limited haemorrhages, especially in lateral hemispherical haematomas, not complicated with abundant extravasation of the blood into the ventricles. Prognosis is worse with poor somatic condition of the patient, especially due to cardiovascular insufficiency.

Prognosis in ischaemic stroke is more severe in extensive hemispherical infarctions due to acute occlusion in the intracranial portion of the internal carotid, associated with dyscommunication of the circle of Willis and occlusion of the main trunk of the middle cerebral artery, as well as in extensive brain-stem infarctions due to acute occlusion in the vertebrobasilar system. Unfavourable signs are those of general cerebral oedema and secondary lesion in the brain stem, general circulatory disorders. Prognosis is more favourable with circumscribed disorders or brain-stem infarctions, in younger patients and with satisfactory condition of the cardiovascular system. Prognosis is better if the cerebral infarction is the result of some pathology of the extracranial portion of a major vessel, and it is far worse, if the infarction is due to pathology of intracranial vessels. Prognosis becomes worse with combined lesion of several vessels, and in a recurrent stroke.

Unfavourable prognostic signs with regard to the life of the patient should be considered to be prolonged (up to 5-7 days) soporocomatose condition and severe forms of clouding of consciousness (state of confusion) with chaotic excitement and speech incoherence. Euphoria, the pseudoparalytic or the Korsakov syndrome in the early period of stroke indicate a probability of psychosis to be transformed into dementia; affective and asthenic disorders following episodes of clouding of consciousness are more favourable with respect to prognosis.

4.17. Prophylaxis

The prophylaxis of stroke includes consistent check-up of the patients suffering from vascular diseases, rational organization of the patient's daily life, work, rest, nutrition, improvement of their working and living conditions, regulation of sleep, correct psychological attitude of the patient, rational and timely treatment of cardiovascular disease, especially if it is hypertensive disease or atherosclerosis, prevention of further progress of vascular disease and recurrent transient disorders of cerebral circulation.

Chapter 5. Disorders of Cerebral Venous Circulation

5.1. Clinical Picture

Clinical manifestations of disturbances of cerebral venous circulation are different and depend on the nature of the pathological process, degree of disorder of the venous outflow, changes in intracranial pressure. The following variants of disturbances of cerebral venous circulation are distinguished: *venous congestion*, *venous encephalopathy*, *venous haemorrhage*, *thrombosis in the veins and venous sinuses*, *thrombophlebitis*. Latent course (as well as grossly severe, sometimes almost fulminant course) of thrombosis and thrombophlebitis of cerebral veins in infants occurs more commonly than in older children or adults.

Venous congestion is the commonest disorder resulting from a variety of causes: cardiac and cardiopulmonary insufficiency, diseases of respiratory organs (bronchitis, bronchiectasis, bronchial asthma, emphysema, etc.); compression of the extracranial veins (the internal jugular, innominate, superior vena cava) by goitre, an arterial aneurysm, tumour in the cervical area; neoplasms in the brain, meninges and cranium, arachnoiditis, a craniocerebral trauma, thrombosis of the veins and sinuses of the dura mater; compression of the veins in hydrocephalus and craniostenosis. Venous congestion causes metabolic changes and cerebral hypoxia, an increase in venous and intracranial pressure, and development of cerebral oedema. Easier disorders appear more often, such as change in the tonus of cerebral veins, which is revealed by means of orbital plethysmography and rheography.

Pathomorphological study shows venous plethora. The brain has a cyanotic tint and is larger in size. Arteries and veins are dilatated. Cross-section of the brain reveals petechial haemorrhages. There are hyperaemia and tortuosity of the capillaries under the microscope, numerous perivascular haemorrhages, growth of the connective fibres in the cerebral meninges, considerable changes in the cells of the brain.

The following symptoms are characteristic for this kind of dis-

turbances of cerebral venous circulation: (1) a dull headache, more pronounced in the morning, growing when the head is moved to the side, when there is a change in the atmospheric pressure, a change in the temperature of the environment, after alcohol uptake, a period of excitement, etc.; (2) a hum or noise in the head; cyanotic tint of the lips, cheeks, ears, nose, mucous membranes of the mouth; (4) swollen lower eyelids, especially in the morning; (5) dilatated veins in the eye fundus; venous pressure varies within the range of 55 to 80 mm H_2O; arterial pressure is usually within normal limits; (6) stupefaction, dizziness, darkening before the eyes, syncopes, numbness in the limbs; (7) epileptiform attacks, psychic disturbances. In pronounced venous congestion the patient is unable to lower his head or take a horizontal position. Venous congestion results from defects of development of the cerebral veins, especially varicose and cylindrical dilatation of the vena cerebri magna (Galen's vein). Symptoms: headache, convulsive attacks, cerebellar disorders, impairment of the function of the craniocerebral nerves.

The important points in the diagnosis of the pathology of the veins are these: *measurement of the pressure in the median cubital vein, cranial radiography* (extensive development of the diploic veins, emissaries, and the veins of the dura mater), phlebography.

There are several syndromes in *venous encephalopathy*: the hypertensive (pseudotumorous) syndrome, that of disseminated small-focused cerebral lesion, bettolepsy (laryngeal epilepsy or laryngeal syncope), and the asthenic syndrome.

The *hypertensive syndrome* is characterized by headache, stupefaction, dizziness, motor disturbance, papilloedema.

The *syndrome of disseminated small-focused lesion* includes the signs of venous congestion and insignificant neurological symptoms: uneven reflexes, asymmetry of the nasolabial folds, nystagmus, difficulty in speech, ataxia.

Bettolepsy, or epileptic cough seizures, develops in chronic bronchitis, pulmonary emphysema, pneumosclerosis, bronchial asthma, especially in cardiopulmonary insufficiency. A spell of persistent cough ends with an epileptiform paroxysm or a sudden loss of consciousness (the syncopal form).

The *asthenic syndrome* is displayed in lassitude, adynamia, rapid exhaustion, superficial and interrupted sleep, emotional instability, vegetative disorders (palpitation, hyperhidrosis, acrocyanosis) occasionally in microsymptoms.

Acute disturbances of cerebral venous circulation include venous haemorrhages, thromboses of the veins and venous sinuses, thrombophlebitis.

Venous haemorrhages arise in haemorrhagic stroke as a concomitant sign. Capillary-venous bleeding into the brain and capillary-venous stasis are observed in hypertensive disease. Venous stroke

occurs in patients with heart failure, a craniocerebral injury, cerebral tumour, infectious or toxic lesions in the brain. Venous haemorrhages develop slowly: clouding of consciousness, speech disorders, diplopia, pyramidal reflexes, hemiparesis, hemihypaesthesia, less often hemiplegia, lesion in the craniocerebral nerves.

Thrombosis of cerebral veins is found in the clinical practice of many specialists as a complication of various inflammatory processes, infectious diseases, operations, abortions, pregnancy, delivery, cranial injuries, heart defects of the blue type, etc. Its pathogenesis is influenced by the change in the vessel walls, reduced rate of blood flow and increased blood coagulability, as well as change in the colloidal properties of endothelial cells, which is conducive to aggregation of haemocytes. Not uncommonly thrombosis of cerebral veins occurs together with thrombosis of the sinuses and the veins of the lower limbs. The brain substance is affected by a local or diffuse oedema, stasis, diapedetic haemorrhages, small foci of necrosis. Haemorrhagic infarction develops in the brain cortex and the adjacent white matter. Prolonged venous congestion results in atrophic change of the cerebral cortex; cysts and porencephaly are found in the necrotized areas.

Thrombosis of cerebral veins usually develops gradually: headache, nausea, vomiting, meningeal phenomena, papilloedema or oedema of the optic nerve, raised body temperature, higher ESR. The cerebrospinal fluid shows mild pleocytosis, elevated protein content, sometimes blood. It is characteristic to observe seizures of the Jacksonian type, clouding of consciousness, less often general convulsions. Focal symptoms occur depending on the localization of the venous affection: aphasia, alexia, hemianopsia, flaccid or spastic paresis or paralysis, impairment of sensitivity. The outcome is not infrequently favourable, the focal symptoms often considerably and sometimes completely regress, but relapses are possible. The course may also be chronic, continuing for many months and even years. Occasionally the sequelae are seen in the form of psychic disorders, aphasia, convulsive attacks and paresis in the limbs.

Differential diagnosis. The clinical picture in cerebral venous thrombosis may be similar to that of a number of diseases: meningoencephalitis, encephalitis, abscesses and tumours in the brain. Besides, medical experts often fail to take into account a possibility of cerebral venous thrombosis, giving preference to more 'customary' diagnoses. Despite the signs of inflammatory process identical to those of meningoencephalitis and cerebral thrombophlebitis (raised temperature, ESR, leucocytosis in the blood, pleocytosis in the cerebrospinal fluid), it is more characteristic for cerebral vein thrombosis to show combinations of the fall-out symptoms and/or irritation of the sensomotor brain areas, especially variable

symptoms (migrating, relapsing, fluctuating ones) with signs of liquorovascular dyscirculation (papilloedema, intracranial hypertension, raised protein content or admixture of blood in the cerebrospinal fluid). It is important for diagnosis to pay attention to earlier diseases and conditions (thrombophlebitis in the lower limbs or the plexuses of the small pelvis, inflammatory foci, infectious diseases, delivery, abortions, operations). It is necessary to take into account the change in coagulogram and concomitant thrombophlebitis of other localization.

Differentiation from an abscess in the brain may be difficult because of identity in aetiology (purulent p ocess in the head, less often of other localization) and similarity of a number of symptoms. However, clinical features of affection in intracerebral veins should be considered.

Thrombosis of cerebral veins with pseudotumorous (hypertensive), a convulsive paralytical or slowly progressing paralytical syndrome is often mistaken for cerebral tumour when the data of the case history, somatic status, findings of the study of the cerebrospinal fluid and blood, and dynamic observation are underrated. Findings of serial angiography, electro- and echoencephalography cross-checked against the clinical picture may and should be considered if there is any difficulty in making a diagnosis.

Difficulties in differentiation of disorders of arterial and venous circulation of the brain are complicated by the fact that cerebral thrombophlebitis may be combined with an arterial affection. Thrombosis of cerebral veins may be characterized not only by disseminated small haemorrhages and haemorrhagic cerebral infarction, but also by large foci which correspond to extensive and stable focal and general cerebral symptoms. That makes differential diagnosis rather difficult; but in most cases thrombosis of cerebral veins is related to small secondary bleeding and haemorrhagic infarction with variable and often mild symptoms. Latent clinical course of thrombosis in cerebral veins makes the clinical symptoms so mild that correct diagnosis is practically impossible during the patient's lifetime, and thrombosis is revealed during the postmortem when the patient dies of some other cause.

Thrombosis of the sinuses of the dura mater usually develops when the sinuses are infected from some nearby focus (a furuncle or carbuncle on the face or hairy part of the head, erysipelas, etc.; purulent osteomyelitis in the bones of the skull, purulent acute and chronic otitis; mastoidits; suppurative processes in the orbital cavity or paranasal sinuses); the infection passes along cerebral and diploic veins. Besides, phlebitis or thrombosis in the sinuses of the dura mater may develop haematogenously in thrombophlebitis of the veins of the limbs or small pelvis, and in septic processes. Thrombophlebitis of the cerebral sinus may be occasionally accom-

panied with thrombophlebitis of the retinal veins, purulent meningitis, cerebral abscess, etc.

Marantic thrombosis of the sinuses occurs in chronic infections (tuberculosis), malignant tumours and other diseases involving cachexia, in emaciated and old patients. Its pathogenesis includes disorder of the coagulative properties of blood, weakening of cardiac activity, deceleration of blood flow, pathology in the lungs, reduced organism's resistance, infection, decubitus, etc. The neurotrophic factor (impairment of nutrition of the venous endothelium) is important, since it may promote thrombus formation. In marantic thrombosis, the most often affected are the superior sagittal or straight sinuses, small cortical veins.

The clinical signs depend on localization of the foci and degree of severity of the brain lesion. The symptoms of the thrombosis of a sinus include subfebrile or sometimes very high stable or varying temperature, headache, vomiting; leucocytosis in the blood, raised intracranial pressure. In thrombosis of a sinus of the convex surface of the brain, general cerebral symptoms are predominant; in thrombosis of the sinus of the base of the brain, the signs of lesion in the craniocerebral nerves prevail. Drowsiness or sometimes, on the contrary, motor excitement, develops; there are insomnia, delirium, epileptiform attacks, rigidity in the occipital muscles, the Kernig sign, hyperaesthesia to visual, auditory, and skin stimulation, occasionally trismus. Focal symptoms of the brain lesion correspond to the sinus localization. Tumefaction and cyanosis of the face or the area of the mastoid process of the temporal bone are present. The eye fundus reveals phlebectasia, papilloedema, occasionally choked disk (in thrombosis of the superior sagittal sinus). The cerebrospinal fluid is transparent or xanthochromic, sometimes with admixture of erythrocytes; moderate pleocytosis may be found. Septic thrombosis of the sinuses of the dura mater is manifested by chill and high and remitting temperature.

Thrombosis of the superior sagittal sinus causes epileptic attacks of the Jacksonian type, hemi- and paraplegia, paresis.

Thrombosis of the transverse sinus more often occurs in purulent otitis, mastoiditis, osteomyelitis of the temporal bone, pachymeningitis or a dural abscess in the area of the pyramid of the temporal bone. Symptoms of thrombosis in the transverse or sigmoid sinus are headache, bradycardia, sometimes diplopia, septic temperature, chill, stupefaction developing into soporose or even comatose state, occasionally delirium and excitement; pain in the mastoid process under pressure or percussion, pain during chewing, swallowing, and when the head is turned to the healthy side; sometimes an antalgic attitude of the head inclined to the diseased side; meningeal phenomena, leucocytosis in the blood. The jugular vein may also be involved in the process. This causes oedema of the tissue

surrounding the vein, and signs of lesion in the glossopharyngeal, vagus, accessory, and hypoglossal nerves.

Thrombosis of the cavernous sinus occurs predominantly due to suppurative processes in the paranasal sinuses and eye sockets, a carbuncle or furuncle in the nose, upper lip, less often due to suppuration in the mouth. The symptoms are exophthalmos, oedema and venous hyperaemia in the eyelids, eye sockets, forehead, the root of the nose, dilatation of the veins of the eye fundus (congestion), pain and hyperaesthesia in the territory of innervation of the superior branch of the trigeminal nerve, chemosis of the conjunctiva, ophthalmoplegia, i.e. paralysis or paresis of the oculomotor (third, fourth and sixth) nerves, stupefaction, delirium, sometimes comatose state, metabolic and endocrine disorders. Complications: purulent meningitis, metastatic abscesses in the lungs, septic pneumonia.

Thrombophlebitis of cerebral veins causes rise of the temperature to the subfebrile level, with periods of 38-39°C. The patient's complaints are headache, nausea, vomiting. Typical are stupefaction, soporose state, epileptic convulsions, paresis in the limbs; phlebectasia and oedema in the eye fundus; leucocytosis in the blood; mild pleocytosis in the cerebrospinal fluid, raised protein content and positive protein tests, sometimes admixture of erythrocytes in the cerebrospinal fluid. Aggravation of headache in the horizontal position, occasional transient tumefaction and cyanosis under the eyes, noise in the head are also characteristic.

Occlusion in the superior vena cava may occur due to a tumour or an inflammatory process in the mediastinum, sometimes due to an aneurysm of the ascending portion and the arch of the aorta. It causes a lag in the outflow of blood through the internal jugular vein, which results in venous plethora and congestion in the brain, dura mater and its sinuses, labyrinth of the internal ear, venous plexuses of the pharynx, in the larynx, tongue, thyroid gland, etc.

The following triad is characteristic for the syndrome of lesion in the superior vena cava: eodema, cyanosis, and dilatation of subcutaneous veins in the face, neck, upper part of the thorax and the upper limbs. Compression of the superior vena cava causes dull headache and heaviness in the head, noise or hum in the head appearing or aggravating in the horizontal position, especially in the side of compression; dizziness when the position of the head is changed, sometimes foggy vision; periodic impairment of memory and attention, weakness, poor sleep, dyspnoea. Examination reveals asymmetry in the shade of skin of the neck and face, more contrasted in the horizontal position, sometimes acutely positive clino-orthostatic test, pronounced delay in *levelling* out the shade of hands and fingers in the haemodynamic Bogolepov test. Prolonged occlusion of the superior vena cava causes chronic venous spinal insuf-

ficiency. The pathogenesis of intracranial dyscirculatory phenomena is influenced by the degree of venous congestion in the system of the superior vena cava.

Occlusion in the inferior vena cava may develop acutely with oedema, dilatation of subcutaneous veins in the lower part of the trunk and lower limbs, strong pain in the lumbar region and legs, followed by lower paraparesis with decreased or absent tendon reflexes, impairment of sensitivity, painful symptoms of tension, abnormal reflexes, retention of urination. There are pale dermographism, hyperthermia, reduced oscillation index in the lower limbs. Phlebography shows that the contrast substance does not fill the inferior vena cava and the iliac veins.

5.2. Treatment

Treatment aims at control of the inflammatory process, thrombus formation and vasculoliquor dyscirculation. In *venous congestion* patients with heart failure are treated with foxglove (Digitalis L.), adonis (Adonis L.), trimethylxanthine (caffeine, theine), camphor, as well as diuretic preparations: acetazolamide (Diacarb), furosemide (Lasix). The patient should maintain a semi-sitting position, with the head put back. A high pillow is recommended for sleep. Dehydrating preparations are given to lower intracranial pressure and to decrease cerebral oedema. Also indicated are vascular preparations: No-spa, Nicospan, aminophylline (Euphylline). Oxygen is given for inhalation, subcutaneous injection; the patient may be put under an oxygen tent.

In *venous encephalopathy* a favourable effect is produced by remedial exercises, physiotherapy, rational mode of sleep-wake, work and rest schedule. It is necessary to have intervals during worktime, when it is recommended to put the hands behind the head and make some deep breaths. The patient should be on vegetarian diet (vegetables, fruit), containing potassium salts and having diuretic property.

Patient's capacity for work is decreased in case venous congestion is protracted. Work involving weight lifting, inclination of the head, work at altitude or under the ground, at low or high temperature should be excluded.

Venous haemorrhages are treated with vitamin K (Vicasol), calcium preparations, rutoside (rutin, vitamin P), ascorbic acid, intravenous injection of 5 ml of an 0.25-0.5 per cent solution of procaine (Novocaine), and dehydrating preparations: furosemide, mannitol (Osmitrol), glycerine. Symptoms of congestion are decreased with tribenoside (Glyvenol) in a dosage of 0.2 g 3-4 times daily

or 1 capsule of 0.4 g 2 times a day for several weeks, 15 drops of Escusan 3 times a day. Anticoagulants are given in thrombosis and thrombophlebitis of cerebral veins: phenindion (Phenyllin), Syncumar, Heparin. Contraindications are xanthochromia of the cerebrospinal fluid, septic condition. Acetylsalicylic acid, phenylbutazone (Butadion) are also used. It is advisable to give desensitizing drugs, such as diphenhydramine (Dimedrol), promethazine (Pipolphen). Leeches are indicated to be put to the mastoid processes.

Thrombophlebitis of cerebral veins requires anti-infective therapy (antibiotics, sulphanilamides). If necessary, anticonvulsive drugs are given, such as barbiturates, Seduxen, analgesics, cardiac preparations, sedatives. Operation is recommended for purulent processes in the transverse or sigmoid sinus.

Treatment in the residual stage of thrombosis in cerebral veins or the sinuses is similar to the rehabilitation therapy for the residual phenomena of other cerebrovascular lesions.

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